

Draft Forest Management Plan
For
Cashmere Forest,
Port Hills, Canterbury

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Table of Contents

Abstract	xiv
Acknowledgements	xvi
Chapter 1 Introduction	1
1.1 Introduction	1
1.2 Background of Management Planning.....	2
1.3 General Approach of the Cashmere DFM plan	3
Chapter 2 Cashmere Forest Vision and Outcomes	4
2.1 200 Year Vision.....	4
2.2 30 Year Outcome	5
2.2.1 Forest Management.....	5
2.2.2 Ecology (Restoration, Biodiversity)	5
2.2.3 Landscape	6
2.2.4 Recreation	6
2.3 5 Year Outcomes	7
2.3.1 Forest Management.....	7
2.3.2 Ecology (Restoration, Biodiversity)	10
2.3.3 Landscape (inc. Soil & Water).....	10
2.3.4 Recreation	12
Chapter 3 Ecological Context of the Area.....	13
3.1 Background.....	13
3.2 Location.....	13
3.2.1 Physical Location.....	13
3.2.2 Legal Area.....	14
3.3 Physical Attributes	15
3.3.1 Geological History	15
3.3.2 Soils.....	16
3.3.3 Topography	18
3.3.4 Climate.....	21

3.4 Ecological History of the Area	23
3.5 Today's Vegetation Cover	25
3.5.1 Port Hills	25
3.5.2 Cashmere Forest.....	26
3.6 Fauna	29
3.7 Streams	32
3.8 Adjacent Areas	33
 Chapter 4 Production Forest Description	 35
4.1 Introduction	35
4.2 Forest Context.....	35
4.2.1 Forest Boundary.....	35
4.2.2 Forest Area	36
4.2.3 Forest Access	38
4.2.4 Regulatory Limitations	40
4.2.5 Environmental Forest Benefits.....	40
4.2.6 Social Forest Benefits	42
4.3 Forest Description	43
4.3.1 Compartment Area.....	43
4.3.2 Forest Inventory	43
4.3.3 Compartment History.....	44
4.3.4 Stratum Description	45
 Chapter 5 Approach to Economic Evaluation.....	 46
5.1 Introduction	46
5.2 Cost Information	46
5.2.1 Harvesting	46
5.2.2 Haulage	47
5.2.3 Earthworks	48
5.2.4 Silviculture.....	49
5.2.5 Annual Charges.....	50
5.2.6 Indigenous Restoration	51
5.3 Log Grade and Price Information	51

5.4 Economic Evaluation	52
5.4.1 Introduction.....	52
5.4.2 Liquidation Value	53
5.4.3 Discounted Cashflow	53
5.4.4 Discount Rate.....	54
5.4.5 Normal Cashflow	54
5.4.6 Land Area.....	55
5.4.7 Sensitivity Analysis	55
5.5 MARVL Analysis	56
5.5.1 Introduction.....	56
5.5.2 Dictionary	56
5.5.3 Models.....	57
5.5.4 Coupe Harvesting and CCM.....	57
5.5.5 CCM (log trace)	58
5.5.6 Constraints of MARVL Inventory and Software.....	59
 Chapter 6 Economic Evaluation	 60
6.1 Introduction	60
6.2 Liquidation Value.....	60
6.3 DCF – Clearfell Harvesting.....	61
6.3.1 Harvest age.....	61
6.3.2 Sensitivity Analysis	62
6.3.3 LEV	63
6.4 DCF - Coupe Harvesting	64
6.4.1 Harvest Dates	64
6.4.2 Sensitivity Analysis	64
6.4.3 Including CCM	68
6.5 Normal Cashflow – Clearfell Harvesting	69
6.5.1 Background	69
6.5.2 Clearfell Harvesting.....	70
6.6 Normal Cashflow – Coupe Harvesting.....	71
6.6.1 Coupe Harvesting.....	71
6.6.2 Sensitivity Analysis	71

6.6.3 Including CCM	72
6.7 Discussion	73
6.7.1 Liquidation Value	73
6.7.2 DCF	74
6.7.3 Normal Cashflow	76
6.8 Conclusions	77
6.9 Constraints on Economic Evaluation	78
 Chapter 7 Constraints to Management of Cashmere Forest	 81
7.1 Background.....	81
7.2 Environmental Constraints	81
7.3 Forest Management Constraints.....	84
7.4 Biotic Constraints	85
7.5 Regulatory Constraints.....	87
7.6 Economic Constraints	88
7.7 Social Constraints.....	88
 Chapter 8 Forest Park Management.....	 90
8.1 Management Overview	90
8.1.1 Background	90
8.2 Species Choice.....	91
8.2.1 Introduction.....	91
8.2.2 Radiata pine	92
8.2.3 Douglas fir	93
8.2.4 Eucalypts.....	94
8.2.5 Mexican cypress.....	95
8.2.6 Coast redwood	95
8.2.7 Totara & Matai.....	96
8.3 Harvest Plan.....	97
8.3.1 Introduction.....	97
8.3.2 Harvest Plan Objectives.....	97
8.3.3 Roding	98
8.3.4 Landings.....	100

8.3.5 Coupe Harvesting.....	101
8.3.6 Harvest System	103
8.3.7 Slash Management	105
8.3.8 Ground Based Areas	106
8.3.9 Continuous Canopy Management.....	106
8.4 Forest Measurement.....	108
8.4.1 Introduction.....	108
8.4.2 Forest Measurement Objectives.....	108
8.5 Silvicultural Regime	109
8.5.1 Introduction.....	109
8.5.2 Proposed Silviculture Regimes	109
8.5.3 Site Preparation	111
8.5.4 Weed Control.....	111
8.5.5 Fertiliser	112
8.5.6 Radiata pine	112
8.5.7 Douglas fir	113
8.5.8 Eucalypts.....	114
8.5.9 Mexican cypress.....	115
8.5.10 Coast redwood	116
8.5.11 Totara & Matai.....	116
Chapter 9 Environmental Management.....	118
9.1 Introduction	118
9.2 Landscape.....	118
9.2.1 Introduction.....	118
9.2.2 Streams and Riparian Areas.....	118
9.2.3 Erosion	120
9.2.4 Forest Canopy	120
9.3 Indigenous Restoration	121
9.3.1 Background	121
9.3.2 Restoration Planting Approach	121
9.3.3 Species Choice and Placement.....	124
9.3.4 Establishment.....	126

9.3.5 Risk	127
9.4 Recreation	127
9.5 Plant and Animal Pest Management	128
9.5.1 Introduction.....	128
9.5.2 Objectives of Pest Management.....	128
9.5.3 Current Plant and Animal Pests	129
9.5.4 Plant Pest Management.....	130
9.5.5 Animal Pest Management	131
Chapter 10 Management Areas and Actions	134
10.1 Introduction	134
10.2 Management Area 1	135
10.2.1 Description.....	135
10.2.2 Forest Management actions	136
10.2.3 Ecological actions	137
10.2.4 Landscape actions	138
10.2.5 Recreation actions	138
10.3 Management Area 2	139
10.3.1 Description.....	139
10.3.2 Forest Management Actions	140
10.3.3 Ecological actions	141
10.3.4 Landscape actions	141
10.3.5 Recreation actions	142
10.4 Management Area 3	143
10.4.1 Description.....	143
10.4.2 Forest Management actions	144
10.4.3 Ecological actions	145
10.4.4 Landscape actions	147
10.4.5 Recreation actions	147
10.5 Management Area 4	147
10.5.1 Description.....	147
10.5.2 Forest Management actions	148
10.5.3 Ecological actions	149

10.5.4 Landscape actions	150
10.5.5 Recreation actions	150
10.6 Management Area 5	151
10.6.1 Description	151
10.6.2 Forest Management actions	152
10.6.3 Ecological actions	153
10.6.4 Landscape actions	154
10.6.5 Recreation actions	154
Chapter 11 Monitoring	155
11.1 Background	155
11.2 Plantation Area - Growth and Yield	155
11.2.1 Introduction	155
11.2.2 Forest Measurement	156
11.3 Native Biodiversity	157
11.3.1 Introduction	157
11.3.2 Regeneration Monitoring	157
11.3.3 Restoration Monitoring	158
11.3.4 Plantation Areas	158
11.3.5 Riparian Monitoring	158
11.3.6 Fauna Monitoring	159
11.4 Operations Monitoring	159
11.4.1 Background	159
11.4.2 Silviculture	159
11.4.3 Earthworks and Harvesting	160
11.5 Yield, Cost and Revenue Information	160
11.6 Land Area Information	161
11.7 Storage of Forest Information	161
11.7.1 Forest Measurement and Biodiversity	161
11.7.2 Operations Monitoring and Yield, Cost and Revenue Information	162
11.8 Educational Potential of Cashmere Forest	162
Chapter 12 Project Management	163

12.1 Introduction	163
12.2 Project Management	163
12.3 Planning Review	164
12.4 Annual Work Plans	164
12.5 Recreation Plan.....	164
12.6 Subdivision Plan	165
Chapter 13 Closing Statements	166
13.1 Why is this Cashmere DFM plan important to Cashmere Forest?	166
13.2 What happens to Cashmere Forest now?.....	166
13.3 Final Steps to implement Cashmere DFM plan	167
13.3.1 Incorporate the Recreation plan into Cashmere DFM plan	167
13.3.2 Confirm Cashmere DFM plan vision and goals with the PHPTB	167
13.3.3 Seek independent review of Cashmere DFM plan.....	168
13.4 Possible impediments to the Success of the Cashmere DFM plan	168
13.4.1 Subdivision	168
13.4.2 Cashmere DFM plan vision and goals	168
13.4.3 Major disturbance event.....	169
References.....	170
Appendix 1 GIS Project for Cashmere Forest.....	176
1.1 Introduction	176
2.2 List of Views and their Relevance.....	176
1.3 Project Folder Layout.....	178
Appendix 2 Legal ownership	179
Appendix 3 Indigenous Plant List for Cashmere Forest	180
Appendix 4 Regulatory Limitations	182
Permitted Activities Relative to Forestry	182
Rule 1 Permitted Activities - Area i.....	182
Rule 2 Permitted Activities - Area ii.....	183
Discretionary Activities Relative to Forestry.....	183
Rule 3 Discretionary Activities - Area i.....	183

Rule 4 Discretionary Activities – Area ii.....	184
Non-Complying Activities.....	185
Rule 5 Non-Complying Activities – Area i	185
Rule 6 Non-Complying Activities – Area ii	185
Schedule 1 (Relative to Forestry)	185
Conditions for permitted activities.....	185
Schedule 2 (Relative to Forestry)	186
Discretionary activities must comply with the following standards and terms.	186
Schedule 2 cont.	187
Matters to be taken into account when assessing discretionary activities.	187
Appendix 5 Radiata Pine MARVL Dictionary	188
Appendix 6 Douglas fir MARVL Dictionary	189

List of Figures

Figure 3.1: General location of Cashmere Forest and its proximity to Christchurch city.....	14
Figure 3.2: Soils of the Cashmere Forest area from Port Hills Study soil map (CUC 1986) with an approximate boundary of Cashmere Forest.....	19
Figure 3.3: LRI soil erosion risk classification.....	20
Figure 3.4: An example of three different vegetation types (Tussock grassland, Rock association and Mixed shrubland) occurring from left to right in one bluff area of Cashmere Forest.	27
Figure 3.5: Water features present in Cashmere Forest.....	33
Figure 3.6: Indigenous restoration and park areas adjacent to Cashmere Forest.....	34
Figure 4.1: Cashmere Forest boundary and adjacent roads.	36
Figure 4.2: Current production forest compartments and non plantation areas in Cashmere Forest.	38
Figure 4.3: Access roads, main tracks and proposed haul roads and landing sites for Cashmere Forest.	39
Figure 4.4: Location of inventory plots completed in the summer of 2005/2006 in Cashmere Forest.	44
Figure 6.1: NPV's for alternative harvest ages under a clearfell harvest regime in Cashmere Forest.	61
Figure 6.2: Sensitivity of a clearfell harvest NPV to changes in discount rate in Cashmere Forest.	62
Figure 6.3: Sensitivity of clearfell harvest NPV to changes in harvesting and haulage costs in Cashmere Forest.	63
Figure 6.4: Sensitivity of coupe harvest NPV to changes in discount rate in Cashmere Forest....	65
Figure 6.5: Sensitivity of coupe harvest NPV to changes in harvest and haulage costs in Cashmere Forest.	66
Figure 6.6: Sensitivity of coupe harvest NPV to changes in log price estimates for Cashmere Forest.	67
Figure 6.7: Volume predictions from different stand volume models for Stratum1, Cashmere Forest.	68
Figure 6.8: Likely cashflow arising from a clearfell harvesting regime in Cashmere Forest.....	70
Figure 6.9: Likely cashflow arising from a coupe harvesting regime in Cashmere Forest.	71

Figure 6.10: Likely coupe harvesting cashflows following implementation of alternative growth models and silviculture regimes in Cashmere Forest.	72
Figure 6.11: Likely cashflows following implementation of CCM in strata 3 and 6 and subsequent implementation of alternative growth models, silvicultural regimes and restoration in Cashmere Forest.	73
Figure 8.1: Potential locations of haul roads (numbered, refer Table 8.1) and landings for Cashmere Forest.	100
Figure 8.2: An example of possible coupe layout and year of harvest in compartment 8004....	102
Figure 8.3: Proposed areas for ground based and cable harvesting and an example of the average yarding distance (inner circle) and maximum (outer circle) yarding distance for a swing yarder within Cashmere Forest.	104
Figure 8.4: Proposed areas of Cashmere Forest for continuous canopy management.	107
Figure 8.5: Proposed future plantation areas for Cashmere Forest.....	117
Figure 9.1: Current non plantation areas in Cashmere Forest (42.8 ha).	123
Figure 9.2: Proposed future non plantation areas in Cashmere Forest (138.7 ha including riparian).....	123
Figure 10.1: Proposed management areas for Cashmere Forest.....	134
Figure 10.2: Management area 1 and associated features.....	136
Figure 10.3: Proposed future non plantation areas for management area 1.....	138
Figure 10.4: Management area 2 and associated features.....	140
Figure 10.5: Proposed future non plantation, subdivision and road areas for management area 2.	142
Figure 10.6: Management area 3 and associated features.....	144
Figure 10.7: Proposed future non plantation areas for management area 3.....	146
Figure 10.8: Management area 4 and associated features.....	148
Figure 10.9: Proposed future non plantation areas for management area 4.....	150
Figure 10.10: Management area 5 and associated features.....	152
Figure 10.11: Proposed future non plantation areas for management area 5.....	154

List of Tables

Table 3.1: Legend for Figure 3.3 from LRI manual (1992).....	20
Table 4.1: Compartment and strata information for the production component of Cashmere Forest.	37
Table 4.2: Stratum statistics for the production component of Cashmere Forest.....	45
Table 5.1: Price estimates for harvesting operations in Cashmere Forest.	47
Table 5.2: Price estimates for haulage of forest products from Cashmere Forest.	48
Table 5.3: Indicative costs for silviculture operations in the radiata pine component of Cashmere Forest.	50
Table 5.4: Proposed log grades and prices for radiata pine in Cashmere Forest.....	52
Table 5.5: Proposed log grades and prices for Douglas fir in Cashmere Forest.....	52
Table 5.6: Models and tables used within the MARVL program for Cashmere Forest.	57
Table 6.1: Comparative changes to log price estimates for Cashmere Forest.	66
Table 6.2: Forest average percentage change in volume prediction following use of Zhao's models.....	68
Table 6.3: Values and percentage change following implementation of alternative harvest regimes in Cashmere Forest.....	69
Table 8.1: Road and landing cost information for Cashmere Forest.	99
Table 8.2: Aggregated harvest dates and areas for coupe harvesting in Cashmere Forest.....	103
Table 8.3: Initial silvicultural regime for the re-establishment of radiata pine.	110
Table 9.1: Species list of some typical trees and shrubs found in Cashmere Forest and likely additional restoration species.....	125
Table 9.2: Biosecurity threats found in Cashmere Forest.....	129
Table 10.1: Schedule of earthworks and harvesting operations for management area 1, Cashmere Forest.	137
Table 10.2: Schedule of earthworks and harvesting operations for the first 10 years in management area 2, Cashmere Forest.	141
Table 10.3: Schedule of earthworks and harvesting operations for the first 10 years in management area 3, Cashmere Forest.	145
Table 10.4: Schedule of earthworks and harvesting operations for the first 10 years in management area 4, Cashmere Forest.	149

Table 10.5: Schedule of earthworks and harvesting operations for the first 10 years in management area 5, Cashmere Forest.....	153
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Abstract

Cashmere Forest is currently a production forest comprised of mostly radiata pine (c.85%), Douglas fir (c.5%) and some non plantation areas. The Port Hills Park Trust Board (PHPTB) is interested in purchasing Cashmere Forest for the purpose of creating a public forest park environment where forestry, indigenous biodiversity, recreation and the environment are goals of sustainable management. For this purpose this draft forest management (DFM) plan has been prepared. The preparation of the Cashmere DFM plan comprised three main components:

1. An economic analysis of the current plantation component of Cashmere Forest.
2. Preparation of a draft forest management plan which encompasses the management of plantation and non plantation areas.
3. Preparation of a geographic information system (GIS) for Cashmere Forest.

Economic analysis evaluated clearfell, coupe (2 to 5 ha), and a mixture of coupe and continuous canopy management (CCM) as harvesting scenarios. The coupe CCM mix was recommended for implementation primarily as it best suited long term management goals for Cashmere Forest Park while also returning modest value (NPV \$561, 966). Normal cashflow analysis was also used to analyse cashflow over the first thirty years of operation from 2007. Under coupe/CCM, accrued profit does not become permanently positive until around 2019 due to initial infrastructure costs. Accrued revenue culminates at around 4 million after 30 years. This figure may drop following implementation of high pruning, alternative growth models and indigenous restoration.

The Cashmere DFM plan begins with the 200 year vision which sees a Forest Park ecosystem that achieves production, environmental, ecological and recreational goals appropriate to its Port Hills location. Production forestry is practiced through the selective harvesting of a range of naturally regenerated exotic and restored indigenous species. Landscape, soil and water resources are sustainably managed through the retention of a mixed forest canopy. The forest park has been significantly augmented with indigenous flora and fauna typical of the Port Hills and ecologically significant areas are managed specifically for their indigenous biodiversity. Park recreational users are enjoying ongoing utilisation of a unique Canterbury landscape.

Plantation forest management involves coupes of between 2 to 5 ha which will be harvested with cable or ground based systems with areas split approximately 50:50 between the two. Cable harvesting will be carried out with a swing yarder system with ground based operations carried out with track skidders. CCM will be carried out on a trial basis in three compartments. Re-establishment of plantation areas will aim towards occupying around 58% of Cashmere Forest, comprised of areas of radiata pine 65%, radiata pine/eucalypt 24%, Douglas fir/eucalypt 5% and Alternative species 6%.

Non plantation areas are identified as either bluff, track or clearing. Within each area there may be one or more vegetation type including tussock grassland, mixed shrubland, rock association and any mixture of the three. It is proposed that the non plantation area will eventually increase to include riparian buffers 31%, restored native 55%, bluff 10% and track 4% areas, reflecting the long term vision of increased native areas in Cashmere Forest.

Monitoring of forest operations, restoration, recreation and management progress will be integral to the successful implementation of the Cashmere DFM plan. A database of information will be created to allow periodical reviews of processes and predictions and reconciliation of costs and revenues associated with the management of Cashmere Forest. Periodical reviews will also be undertaken by an independent management advisory group who can liaise with the project manager of Cashmere Forest Park to discuss issues and aid planning and ensure the successful establishment of this unique park resource.

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Chapter 1

Introduction

1.1 Introduction

Cashmere Forest is a production forest comprised of mostly radiata pine (c.85%), Douglas fir (c.5%) and some non plantation areas, and has recently been made available for tender by the current owners McVicars Timber Group Limited. The Port Hills Park Trust Board (PHPTB) is interested in purchasing Cashmere Forest for the purpose of creating a public forest park environment where forestry, indigenous biodiversity, recreation and the environment are goals of sustainable management. This masters thesis research aimed to develop the draft forest management (DFM) plan to aid management of the proposed Cashmere Forest Park.

The preparation of the DFM plan comprised three main components:

1. An economic analysis of the current plantation component of Cashmere Forest.
2. Preparation of a draft forest management plan which encompasses the management of plantation and non plantation areas.
3. Preparation of a geographic information system (GIS) for Cashmere Forest.

Prior to undertaking an economic analysis of Cashmere Forest a forest inventory was necessary to capture pertinent forest measurements to assess the state of the forest and from which to make growth and yield predictions. As no previous data was available a reasonably intensive survey (c.2%) was completed using the method for assessment of recoverable volume by log type (MARVL) inventory system. Yield and revenue predictions were then analysed with cost estimates under a number of management scenarios to predict their net present value (NPV) and likely cashflows in Cashmere Forest.

The DFM plan begins by outlining visions and goals for Cashmere Forest and then provides a background to the current state of the area. NPV and cashflow predictions are then used to support forest and environmental management through a series of management actions. Proposed

ongoing collection of forest and monitoring information will provide important feedback on the success of management systems and actions, and further information for forest growth and yield predictions. The DFM plan is prepared as a guiding document from which annual work plans will be devised to carry out management actions.

The GIS component of this project is largely software based with most of the information stored and presented via GIS layers in the Cashmere Arcview project (Appendix 1). Some key GIS information is presented throughout the DFM plan in the form of tables and maps.

1.2 Background of Management Planning

Management plans are a useful management tool that act as a medium for a set of overarching goals for a certain concept and the means by which those goals will be achieved (Carlsson 1998). In the case of the Cashmere DFM plan goals are used to promote multiple values that are seen as integral to the successful management of this proposed forest park. These values include forest management, ecology, landscape and recreation.

Traditionally forest management did not consider ecological, landscape or recreational values however with the introduction of sustainable management through the Resource Management Act 1991 (RMA) and the Forests Act 1993 these issues have become more important. The RMA and the Forests Act both promote production, environmental and social values as policy. Addressing multiple values in forestry is described by Carlsson (1998) as “Ecological Landscape Planning”. Valentine (1995) and Boyce (1995) both outline the importance of considering social, economic and environmental values together with landscape values in forest management planning. This multi-value planning can lead to tradeoffs between competing values (Lawson & Manning 2003). Spatial separation of plantation and native biodiversity areas and temporal separation of operational and recreational forest users is feasible solution for Cashmere Forest. A management document such as the Cashmere DFM plan provides the means for each of these values to be presented in one document, ensuring full integration of values and their goals throughout management decision making. This will also facilitate the consideration of all values when actual on-the-ground work is scheduled through annual work plans.

1.3 General Approach of the Cashmere DFM plan

The DFM plan begins by outlining visions and goals for Cashmere Forest. Initially a 200 year vision is provided which combines key long term management outcomes into one statement. The means by which this vision will be attained is addressed through 30 year and 5 year goals or outcomes. Outcomes detail the management necessary at key times to work towards the forest vision. The most applicable 5 year outcomes include explanations and performance indicators.

Following this a detailed background is provided of key features of the general Banks Peninsula and Port Hills area and more specifically Cashmere Forest. A detailed geological and ecological history relate how past events and management have shaped the current state of Cashmere Forest and the general area. More specific information is provided on the separate plantation and non plantation components in Cashmere Forest. This information is combined with findings from economic analyses to help shape future management decisions.

General management plans and constraints are formulated for future environmental and plantation forest management of Cashmere Forest. These plans are then implemented through specific management actions in designated management areas. Management actions cover forest management, ecological and landscape components of the forest with recreation covered in a separate document.

The collection of monitoring and forest information is proposed for all facets of forest management. Monitoring information will provide a measure of success for indigenous restoration operations and the level of improvement in native biodiversity. Forest information will aid in forecasting growth and yield of plantation species in Cashmere Forest so harvest revenues and forest cashflow can be planned. Project management is then discussed with suggestions on the type of management structure that would be suitable for this type of project.

Chapter 2

Cashmere Forest Vision and Outcomes

2.1 200 Year Vision

The 200 year vision for the Cashmere Forest sees a Forest Park ecosystem that achieves production, environmental, ecological and recreational goals appropriate to its Port Hills location. Production forestry is practiced through the selective harvesting of a range of naturally regenerated exotic and restored indigenous species. Landscape, soil and water resources are sustainably managed through the retention of a mixed forest canopy. The forest park has been significantly augmented with indigenous flora and fauna typical of the Port Hills and ecologically significant areas are managed specifically for their indigenous biodiversity. Park recreational users are enjoying ongoing utilisation of a unique Canterbury landscape.

2.2 30 Year Outcome

(A 30 year outcome period will see all the areas that have been established and treated silviculturally by McVicars under selective harvest for at least 5 years within a 30 to 40 year rotation.)

2.2.1 Forest Management

1. The Cashmere Forest Park cover will be a mosaic of re-established production forest comprising several species, mature production forest and non plantation areas.
2. Coupe and selection harvesting of radiata pine will be occurring or have occurred over around 85% of the production forest.
3. Establishment of suitable production species other than radiata pine in appropriate areas will be advanced and requiring appropriate silvicultural management to enable future high value returns.
4. The database of PSP information for the Cashmere Forest (inc. production and indigenous areas) will be well established describing forest health, regeneration, growth, treatments and removals.
5. Projections for yield and costs associated with forest management and operations will have been updated based on actual data as harvesting occurs every 2 to 5 years.
6. An appropriate silvicultural plan for re-established areas will have been implemented to optimise future forest value.
7. The existing track system will have been extended and upgraded to allow vehicle access appropriate for forest management to around 95% of the forest area.

2.2.2 Ecology (Restoration, Biodiversity)

1. Indigenous restoration of appropriate clearings, tracks and harvest areas will be under way.

2. Around 60% (26ha) of riparian areas will now be occupied by native restoration along designated streams.
3. The small dams within the forest will have significant indigenous restoration established.
4. Where possible mammalian pests will be controlled to levels that allow the persistence of key native bird species within Cashmere forest.

2.2.3 Landscape

1. The Cashmere Forest Park cover will be a mosaic of re-established production forest comprising several species, mature production forest and non plantation areas.
2. The small dams within the forest will be fully restored and operating as part of the stream network.
3. Areas that are significant or have been damaged along the stream network will be under remedial restoration.
4. Softening of plantation edges with indigenous and other exotic species will occur as appropriate areas become available for re-establishment.

2.2.4 Recreation

1. An extensive range of recreation opportunities are available within the forest throughout most times of the year and are actively used by the people of Christchurch.
2. Production forestry is managed to minimise conflict with recreational opportunities.

2.3 5 Year Outcomes

(A 5 year outcome allows completion of silvicultural work in areas requiring it and the start of restoration work in non forest areas.)

2.3.1 Forest Management

Outcome 1: The establishment of a Cashmere Forest Park management advisory group has occurred with meetings held at least two times per year.

Explanation: A management advisory group that includes respected professional and academic people relevant to the management of Cashmere Forest will provide expert advice, aid good decision making and maintain the focus of the Cashmere Forest Vision.

PI: The Cashmere Forest management advisory group is well established and meeting regularly.

Outcome 2: Some coupe harvesting has occurred in the production forest.

Explanation: Coupe harvest entries will begin as compartments reach around 25 years for the production forest. Compartments planted in 1979 and 1980 will have areas in suitable age classes to harvest. Some re-establishment of harvested areas will be underway.

Performance Indicator (PI): Harvesting operations have been carried out once in stratum¹ 6 & 7 and twice in stratum 1, 3, 5, 9 & Dfir² amounting to c.62 ha. Re-establishment of first visit harvest coupes will be completed.

Outcome 3: Weed suppression in areas of the youngest radiata pine has occurred.

Explanation: Weeds are currently competing for resources with young radiata pine in stratum 11. Within 5 years canopy closure should have occurred resulting in significant weed suppression.

PI: Significant weed die-back is occurring in stratum 11 due to light reductions following canopy closure. This will be assessed during forest inventories and auditing of silviculture operations.

¹ A stratum is an aggregation of stands with similar treatment history and/or stand statistics like stocking and volume (Chapter 4, Stratum Description page 44).

² The term Dfir is a distinguishing label for the sole stratum of Douglas fir currently established in Cashmere Forest.

Outcome 4: Silvicultural treatments has occurred in the radiata pine (est.1994 to 2002) and in the older Douglas fir (est.1980).

Explanation: No thinning or pruning treatments have been carried out in stratum 2 & 11, radiata pine. Low pruning and thinning are required to improve access in stratum 2 and create clearwood and growing space for residuals in stratum 11. A second waste thinning of the old Douglas fir (stratum 5) is required to create growing space.

PI: Thinning and, where appropriate, low pruning operations have been scheduled and carried out in strata 2, 5 & 11. This will be assessed during auditing of silviculture operations.

Outcome 5: A formal harvest plan has been implemented.

Explanation: A formal harvest plan is required to update demarcation of ground based and cable logging areas, schedule coupe harvests and arrangement, and where necessary to adjust and finalise location of haul roads and landings.

PI: The formal Cashmere Forest Harvest Plan has been completed by a suitably experienced forest manager and is under implementation with regular consultation prior to and following harvest years.

Outcome 6: The main access track (5.6 km), appropriate haul roads (c.3 km) and related landings have been constructed to a standard suitable for use by logging trucks.

Explanation: Roads are an essential component of forest management. They provide access and exit routes and facilitate park utilisation and management. Road construction is only undertaken where and when new harvest access is required and is scheduled to take place the year prior to harvest.

PI: Construction of the main access track is completed at the end of the first year. Haul roads to provide harvest access to strata 1, 3, 5, 6, 7, 9 & Dfir and landings (1, 2, 5, 7, 8, 10 & 11) have been constructed and are in use by all forest users.

Outcome 7: Planning for the extension of the existing database of PSP information for Cashmere Forest (inc. production and indigenous areas) will be completed with further data collection undertaken as required.

Explanation: Ongoing data collection or re-measuring of PSP's is fundamental for successful forest management in Cashmere Forest. Further PSP's will require establishment in stratum 11 and as areas harvesting and re-establishment takes place. Data collection aims to describe forest health, establishment success, growth, costs of silvicultural treatments, harvesting and removals

and restoration success. Recording and analysing forest information creates opportunities for good decision making in the future.

PI: PSP's have been re-measured in those stratum scheduled for harvest and established in stratum 11. Systems are in place to collect, record and analyse all forest information.

Outcome 8: Auditing of yield, cost and revenue predictions has been carried out with new PSP and actual management data collected from pre-harvest inventory and harvest volume and cost information.

Explanation: Initial estimates of growth, costs and revenues associated with forest management require auditing and updating with real data from Cashmere Forest to facilitate accurate forecasting of all facets of forest management.

PI: Harvest yield and cost information from completed forest operations (harvesting, transport, revenue, re-establishment etc.) has been collected, recorded and used to update modelling estimates where necessary.

Outcome 9: A plant and animal pest management strategy has been implemented.

Explanation: Plant and animal pest management is essential to minimise the risk of biosecurity threats in Cashmere Forest and to surrounding properties.

PI: A formal plant and animal pest management strategy has been written by a suitably qualified professional and has been implemented within the first year. Plant and animal pest management is regularly reviewed through production forest inventories and biodiversity monitoring.

Outcome 10: The forest is regularly used as a resource for education and summer employment.

Explanation: Biodiversity monitoring, production forest inventories, restoration plantings, and production species establishment and silviculture all provide learning and employment opportunities for local students. Utilising students to do research can sometimes avoid the expense of local contractors.

PI: A liaison is established between the forest manager and local educational institutes to facilitate research and operational work by students.

2.3.2 Ecology (Restoration, Biodiversity)

Outcome 11: An in depth indigenous survey of non plantation areas has occurred to aid in ecological restoration of flora and fauna.

Explanation: It is important to identify all facets of indigenous biodiversity in Cashmere Forest and especially to identify threatened and uncommon flora and/or fauna which may require special protection/restoration.

PI: Regular monitoring of forest biodiversity, birdlife and stream life is ongoing. Existing species lists for non plantation areas have been updated and surveys of stream fauna have been completed.

Outcome 12: A formal restoration plan has been completed for current and future non plantation areas in Cashmere Forest.

Explanation: A formal restoration plan is important for scheduling and planning of restoration activities. Good planning and scheduling can highlight priority areas and ensure they are restored in the appropriate manner to maximise restoration success.

PI: A formal restoration plan has been implemented and has been reviewed at least once based on forest biodiversity and restoration monitoring.

Outcome 13: Indigenous restoration along the main access route and within appropriate harvest sites, non plantation and riparian areas will have commenced up to a level of 1 ha per year.

Explanation: The main access route, riparian and summit areas have been chosen for initial restoration investment due to high public use and biodiversity importance respectively. The high cost of indigenous restoration (c.\$40 000 per ha.) limits initial restoration to one ha. per year.

PI: Around 5 ha. of indigenous restoration will have been completed in the areas outlined above. The success of this restoration will be reviewed regularly with restoration and forest biodiversity monitoring.

2.3.3 Landscape (inc. Soil & Water)

Outcome 14: The Cashmere Forest Canopy is progressing towards a more heterogeneous visual landscape than it is at present.

Explanation: The current radiata pine canopy is fairly continuous across the entire forest ending abruptly at forest edges.

PI: Indigenous restoration and establishment of alternative exotic species as production and amenity plantings is underway in appropriate areas (namely riparian and summit non plantation, moist and sheltered production, and high public use areas). The success of these plantings is reviewed regularly through restoration monitoring and production forest inventories.

Outcome 15: All dams in the forest are capable of holding significant reservoirs of water with indigenous restoration planned.

Explanation: Dams originally built for stock watering have collected sediment following forest tracking and salvage operations and are no longer viable. Re-constructing these dams provides water reservoirs for fire fighting purposes and important sites for indigenous restoration.

PI: Remedial excavation work has been completed on all dams and water is collecting behind them. Indigenous restoration around the dams is scheduled.

Outcome 16: A survey of the stream network to identify ecologically significant and/or degraded areas requiring remedial restoration has occurred.

Explanation: Good water quality is important for maintaining stream life and downstream water quality. Past forest operations and grazing cattle have degraded the stream network in places. The need to remove existing production species from stream areas may result in further damage although this will be avoided or minimised where possible.

PI: Stream water quality and life has improved since purchase of the property. Regular surveys of water quality and aquatic life are undertaken to review the effects of forest harvesting and the subsequent establishment of riparian areas.

Outcome 17: A roading survey of the forest to identify high risk erosion sites, soil depth and road lines has occurred to aid forest harvest planning.

Explanation: The steep terrain, underlying rock and varying soil depth characteristic of the Port Hills requires careful consideration in planning for road placement and construction. Surveys can save considerable cost by identifying good routes while minimising earthworks and impacts on the landscape.

PI: There are favourable reports following regular environmental auditing of road construction and maintenance to date.

2.3.4 Recreation

Outcome 18: The main access route is suitable for pedestrian and 2x4 access.

Explanation: Multiple use forests require good vehicular access to facilitate use and provide routes for health and safety reasons.

PI: The main access track is regularly used by forest users and 2x4 forest management vehicles.

Outcome 19: Forest information boards outlining access, management, fire and safety issues are available upon Cashmere Forest opening to the public.

Explanation: Transparency in operations and management is essential for public awareness and support. For example, forest operations and pest management may restrict public access to certain areas of the forest at times. Good methods for notification are therefore essential.

PI: Public information boards are erected at all main entry and high public use points. Signs directing public to information boards and exits are also in place throughout the forest.

Outcome 20: Haul roads are available for recreational use when not operational.

Explanation: Haul roads can provide further vehicular access to Cashmere Forest improving health and safety access and the general recreational track network.

PI: Public and forest management staff are regularly using established haul roads.

Outcome 21: The public are happy with all aspects of the management of Cashmere Forest Park.

Explanation: A primary goal of Cashmere Forest Park is the extension of the existing public recreation domain within the Port Hills environment. Therefore regular public patronage is a measure of success in attaining this goal.

PI: Surveys of recreational users is resulting in positive feedback concerning management of Cashmere Forest Park.

Chapter 3

Ecological Context of the Area

3.1 Background

This section provides an overview of the location and ecological context of Cashmere Forest. Cashmere Forest is situated within the Banks Peninsula Ecological Region and more specifically the Port Hills Ecological District. There has been extensive ecological work including soil and vegetation mapping done on the general Port Hills area due to its interesting history and ongoing importance to the Christchurch landscape. The application of this surrounding ecological data to Cashmere Forest is appropriate for explaining specific natural history and processes as the historic data for this area is currently insufficient.

3.2 Location

3.2.1 Physical Location

Cashmere Forest (Figure 3.1) is situated on the northern flanks of the Port Hills, Banks Peninsula Lat. 43° 36'S Long 172° 38'E. The forest is bounded by Dyers Pass Road to the East, Summit Road to the South and Worsleys Road to the West. The Northern boundary is occupied predominantly by farmland owned by Graeme McVicar and various other residential landowners. Cashmere forest is comprised of two main valleys both descending from Marleys Hill (502m) and the summit ridge (Port Hills) in a northerly direction towards the suburbs of Cashmere and Westmorland. Road access on three sides and adjacent city suburbs ensure that Cashmere Forest is an easily recognised component of the Christchurch landscape.

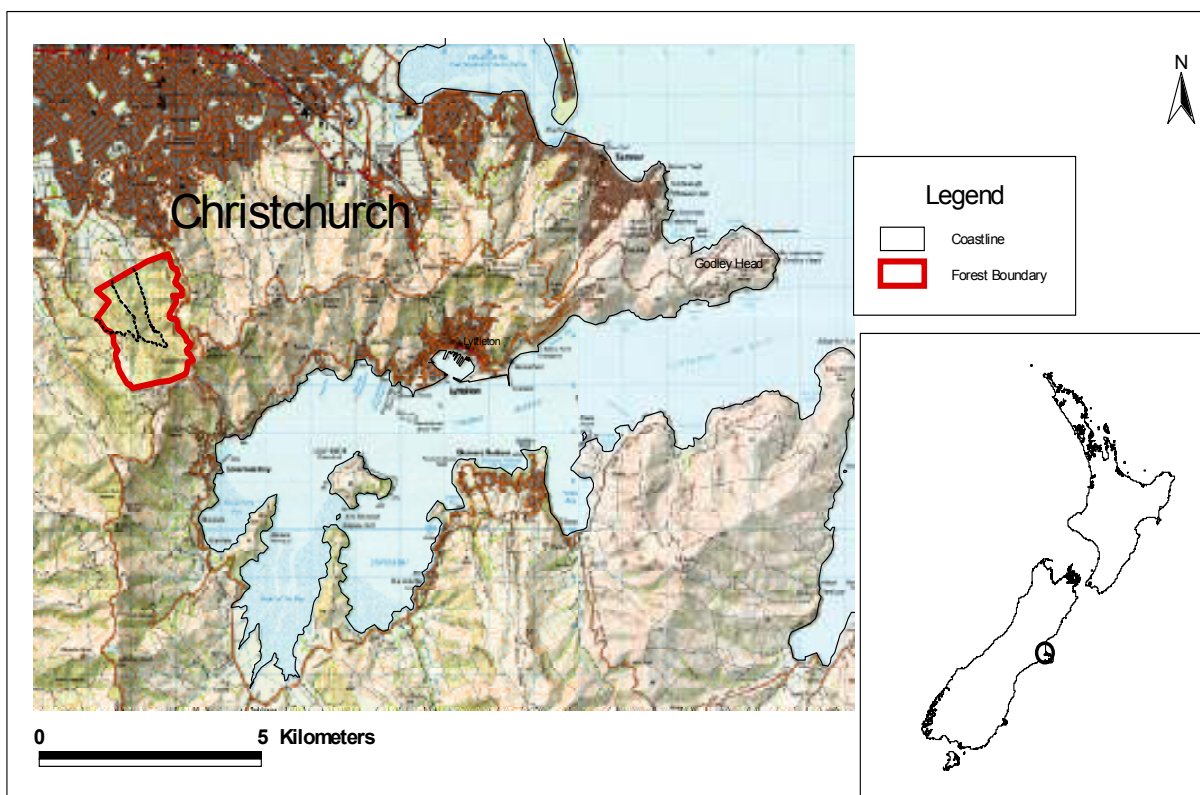


Figure 3.1: General location of Cashmere Forest and its proximity to Christchurch city.

3.2.2 Legal Area

The legal land area of the proposed Cashmere Forest (380.85 ha) is reported in Appendix 2. These area figures were sourced from the Environment Canterbury (ECan) website on the 4th of May 2006. The figures differ slightly from previously presented area estimates in “Options for future use of Cashmere Forest Park” (Port Hills Park Trust Board (PHPTB) 2004). The above publication describes the total land area as 379.39 ha which is c.1.46 ha (or 0.3%) less than the estimate in Table 1. GIS mapping of the legal boundary from an aerial image yielded an area figure for the land as 383.08 ha. This discrepancy is 0.6% different to the ECan area figure and may arise due to irregularities in the boundary used in the GIS system.

3.3 Physical Attributes

3.3.1 Geological History

Cashmere Forest lies within the Port Hills which encompass the northern and southwest sides of Lyttleton Harbour. Lyttleton Harbour and Akaroa Harbour are two of the eroded craters of three extinct volcanoes from which Banks Peninsula Island was largely formed around 10 to 15 million years ago (Canterbury United Council (CUC) 1986). The oldest rocks found on Banks Peninsula are however much older than this. The description by Weaver *et al.* (1985) of these rocks and the subsequent geologic history of Banks Peninsula is broadly as follows. The oldest rocks of Banks Peninsula are around 240 million years old and are found around Gebbies Pass. Referred to as Torlesse Terrane these rocks are sedimentary in nature originating through uplift from the sea floor around 15 million years ago and are common to the Southern Alps, Marlborough Ranges and main ranges in the North Island.

The oldest volcanic rocks of Banks Peninsula are also found around Gebbies Pass and McQueen's Valley. These rocks were erupted around 90 million years ago from sometimes explosive ignimbrite eruptions of the McQueen's Volcanics consisting predominantly of andesite and rhyolite. The volcanic field from which these eruptions occurred has now largely disappeared due to erosion. Following this period of volcanism, sedimentary deposits from Charteris Bay suggest that volcanic activity temporarily ceased and that Banks Peninsula was submerged beneath the sea from c.65 to c.20 million years ago.

The first rumblings of the Kaikoura Orogeny were probably responsible for the uplift of land around 15 million years ago (mid-Miocene Period) that then formed the geologic backbone of modern day New Zealand. This timing coincides with the onset of the Governor's Bay Volcanics from which the majority of modern day Banks Peninsula was formed. This period of volcanic activity which involved 5 eruptive centres extended to around 6 million years ago. Eruptions centred on Governors Bay, Lyttleton, Mt Herbert, Akaroa and Diamond Harbour occurring chronologically in that order in a general south easterly direction producing rhyolite, basalt/trachyte and basalt lavas. New eruptions from vents on the Lyttelton and Mt Herbert

Volcanoes (Diamond Harbour Volcanics) produced the last volcanic activity for Banks Peninsula around 5.8 million years ago.

Since then erosion and deposition of volcanic and loessial material have been the major geologic processes on Banks Peninsula. Millennia of stream flow along valleys and wave action against cliffs has been responsible for further erosion of lava deposits. Glacial periods over the last 2 million years resulted in the production of fine silt which was blown and deposited as loess up to 20 m thick on the flanks of Banks Peninsula. The same glacial processes resulted in the erosion and transfer of debris extending out from the Southern Alps to form the Canterbury Plains. Some time in the last 20 000 years these shingle plains continued their expansion, connecting what was once Banks Peninsula Island to the South Island. This connection has remained despite post-glacial melting of ice and rising sea levels over the last 10 000 years.

3.3.2 Soils

The majority of loess deposition on Banks Peninsula occurred in the late Pleistocene with glacial induced frost-lift and freeze-thaw cycles initiating almost immediate downslope re-deposition of loess. This was prevalent on shady south slopes which may have remained frozen for the duration of winter (Griffiths 1974). As deposition and erosion process occurred, loess was layered and mixed with other loess and volcanic basalt to form four broad soil groups.

1. In areas below 270 to 300 m elevation in a subhumid climate eroded loess forms colluvium above deposited loess resulting in layering and later mixing through soil fauna of loess colluvium and loess producing soils of the Takahe Series. These soils often reach wilting point over summer and form hard fragipan layers.
2. In areas above 270 to 300 m elevation (humid climate) with rainfall greater than 800mm where loess is deposited over basalt, soils are referred to as Summit Series. These soils seldom reach wilting point although this may occur if found on north facing slopes.
3. In areas below 270 to 300 m elevation in a subhumid climate on steep slopes where most loess has been stripped away exposing the underlying bedrock to weathering. Predominantly weathered basalt mixes with residual loess to form soils of the Cashmere Series. Higher field capacity and soil moisture make these soils different from Takahe Series soils.

4. In areas above 270 to 300 m elevation (humid climate) on rolling ridge tops and shoulders where most loess has been stripped away exposing the underlying bedrock to weathering. Weathered basalt mixes with some residual loess to form soils of the Rapaki Series.

Within and between these four broad series there are intergrades (e.g. silt loam) and complexes which result in an extensive list of soil types covering pure loess, loess colluvium, loess/volcanic colluvium to pure volcanic soils for the Banks Peninsula area. Distribution of this range of soil types is very diverse with types grading into one another to form series complexes (e.g. Takahe-Cashmere). This heterogeneous distribution is largely a result of deposition and erosion processes, climate and topography (Griffiths 1974).

CUC (1986) map a mixture of loessial (Takahe hill, Takahe silt loam, Summit hill, Summit hill-Rapaki hill), loess colluvium (Heathcote silt loam, Kiwi hill), mixed loess volcanic colluvium (Clifton hill) and volcanic soils (Evans steepland, Cashmere silt loam, Cashmere hill) in the Cashmere Forest area (Figure 3.2). Of these, loess, loess colluvium and volcanic soils dominate. Where loess and loess colluvium occur on north facing slopes with thick deposits the risk of tunnel gully erosion, rapid mass movements (side slip) and sheet erosion becomes slightly to moderately severe (Figure 3.3). North facing slopes are also likely to be drier and therefore open up creating surface cracking. Surface cracking initiates tunnel gully erosion which facilitates the ongoing down-slope redeposition of loess and loess colluvium. A 17% reduction in soil moisture was found by Boyce (1939) when comparing north facing slopes to south facing slopes in Cashmere Valley following an extensive period of dry weather.

3.3.3 Topography

Banks Peninsula and the north side of Lyttleton Harbour (Port Hills) in particular display typical topography for a volcanic crater with steep radial ridges on the inside walls of the crater rim and more gently sloping radial ridges on the outside. These more gently sloping ridges with side spurs occurring along their length, form the dominant landscape of Cashmere Forest. The central ridges of Cashmere Forest run in a northerly direction with side slopes facing from southwest clockwise to southeast with northwest to northeast predominating. The deposition and erosion of loess on these ridges has resulted in easy lower slopes grading into steeper upper slopes with rocks and rocky outcrops becoming exposed further upslope. Plot information from forest inventory gives the average slope of the forest at 23.1°. This increases to 25.3° when ridge tops and lower slope plots are removed. Cashmere Forest extends from an altitude of around 40 m a.s.l. on the valley floor to around 450 m a.s.l. below the summit of Marleys Hill.

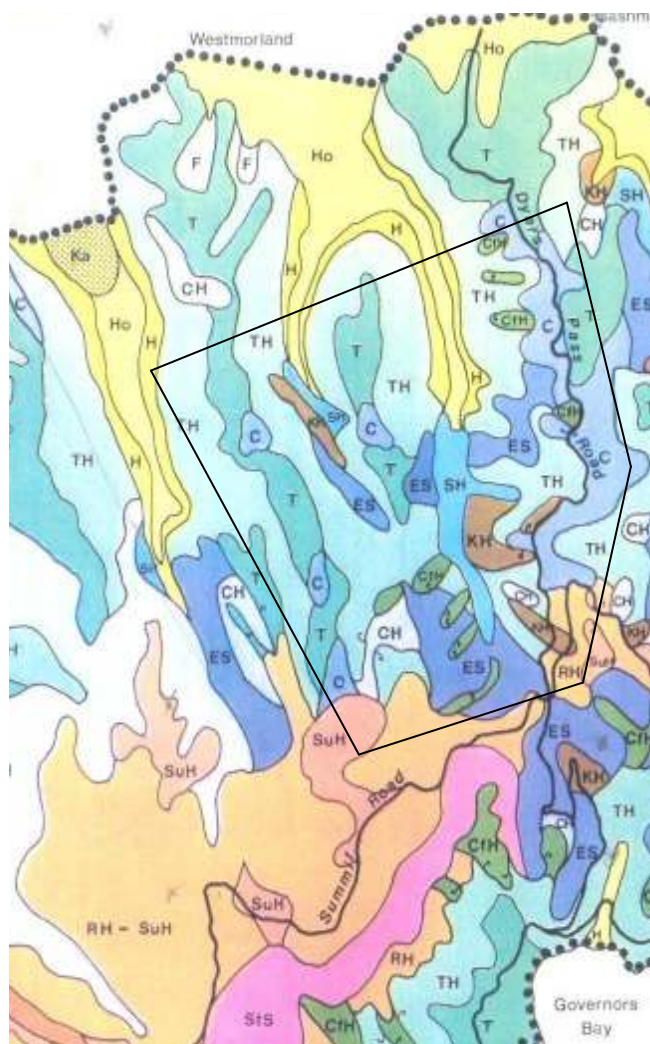


Figure 3.2: Soils of the Cashmere Forest area from Port Hills Study soil map (CUC 1986) with an approximate boundary of Cashmere Forest.

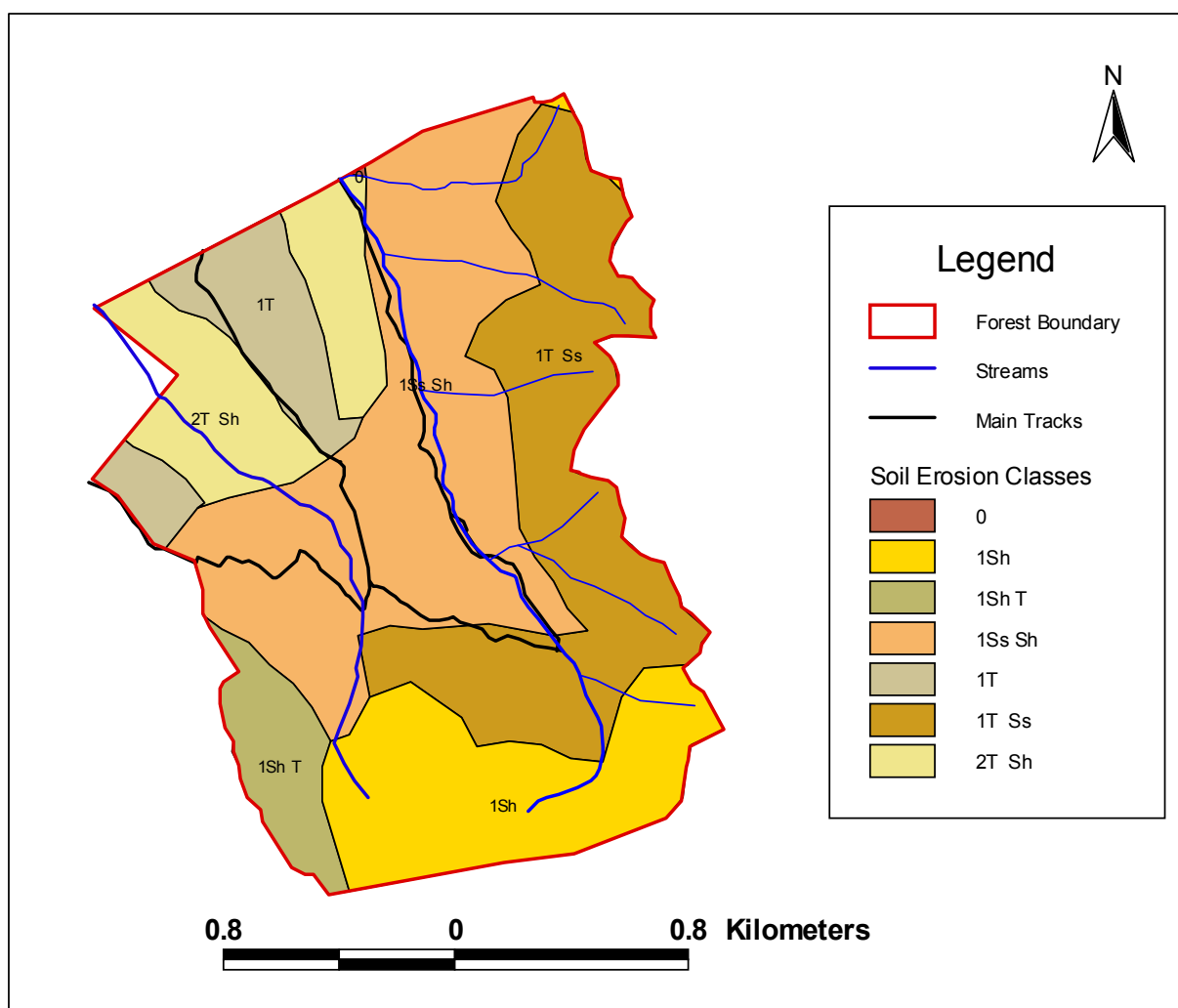


Figure 3.3: LRI soil erosion risk classification.

Table 3.1: Legend for Figure 3.3 from LRI manual (1992).

Severity	Severity expression	Area affected (Sheet only)	Symbol	Erosion Type
0	negligible	negligible	T	Tunnel Gully
1	slight	1 - 10%	Ss	Soil slip
2	moderate	11 - 20%	Sh	Sheet
3	severe	21 - 40%		

The first erosion type listed in a description is the dominant form

3.3.4 Climate

The primary synoptic feature of the South Island climate is the west to east movement of anticyclones separated by frontal troughs and occasionally secondary depressions. This causes a dominant westerly airflow which may be interrupted by tropical cyclones and the development of secondary frontal troughs (Sturman *et al.* 1984). In a relatively flat region like Canterbury irregular terrain like Banks Peninsula can be important in the broad scale air movement by inducing convective development and convergence of local wind systems (Goulter 1982). Sturman (1986) and Trewinnard & Tomlinson (1986) found evidence of this in irregular rainfall patterns around Banks Peninsula.

Rainfall

Banks Peninsula provides an obstruction to air and cloud movement in both directions between the Canterbury Plains and the Pacific Ocean. Slight rainshadow effects on Christchurch city (600 to 700 mm, southwest flow) and adjacent areas to the southeast (northeast flow) are reported by CUC (1986) and Trewinnard & Tomlinson (1986).

Convective development by Banks Peninsula results in higher annual rainfall than the surrounding Canterbury Plains (Goulter 1982; Sturman 1986; Trewinnard & Tomlinson 1986). Precipitation generally decreases from west to east along the Port Hills and from higher to lower elevations (CUC 1986; Griffiths 1974). This is supported by Ryan (1987) who points out the complexity of the relationship which may be due to exposed sites and the valleys that run in a radial fashion. Rainfall data for the 1960s (Griffiths 1974) supplied by the North Canterbury Catchment Board is supported by Cullen (1996) and describes rainfall of c.750mm at lower elevations increasing to c.1020mm at higher sites (> 300m) with increasing rainfall on south facing slopes. Ryan (1987) describes how around 75% of the rainfall east of the Southern Alps originates from southwest airflows with the remainder coming from the east to northeast. This general pattern applies to Christchurch and the Port Hills with 75% of rain coming with wind directions between south and west, c.50% of this rain comes from southwest winds which blow around 20% of the time (McGann 1983)

Wind

The Southern Alps, Canterbury Plains, Banks Peninsula and surrounding ocean all have important impacts on the wind experienced by the Christchurch area. The Southern Alps provide a barrier to mid latitude westerlies at the synoptic scale which results in higher frequencies of wind from the southwest and northeast. They are also responsible for the warm föhn nor'wester wind which occurs as a north-westerly airstream flows over the South Island. The north westerly airstream also causes funnelling of low level air through Cook Strait which recurves onto the Canterbury coast north of Banks Peninsula as a north-easterly wind (McKendry & Sturman 1983; McGann 1983). The heat differential between the Canterbury Plains and the Pacific Ocean to the east often causes a north-easterly sea breeze to typically occur during summer afternoons (Sturman & Tyson 1981). This effect and the recurving of air funnelled through Cook Strait combine to make the north-easterly wind the predominant wind source in Christchurch (Ryan 1987).

While the north-easterly wind dominates Christchurch during summer the south-westerly shares equal significance during winter months. Cool, moist southwest winds which usually accompany cold fronts passing over the South Island have some of the strongest wind of the Christchurch area. Southwest wind frequently replaces a warm dry nor'wester signalling abrupt changes in temperature and humidity (McKendry & Sturman 1983).

The strongest winds in the Canterbury area come from the southwest and northwest, with southwest winds more frequent near the coast. While the northwest wind only blows around 3% of the time (Ryan 1987) its strength and drying effect determines its regional significance (Sturman 1986; McGann 1983; McKendry & Sturman 1983). The strength and relevance of the southwest wind is evident in large areas of windthrow that occurred in 2000 on Cashmere Forest slopes exposed to the southwest direction under Dyers Pass Road.

The barrier that Banks Peninsula provides to wind from all directions results in funnelling and convergence of airflow. These characteristics are typically seen in gusts occurring across saddles and down valleys. Banks Peninsula is also responsible for shielding Christchurch City and the Port Hills from the majority of wind originating from the southeast (McGann 1983).

Temperature

Christchurch generally has warm summers and cold winters with hottest temperatures coming with nor'wester winds. January is typically the warmest month with a mean daily maximum of 21.4°C, although the temperature has reached 41.6°C (February 1973) in nor'wester conditions. July is the coldest month with a mean daily maximum of 10.2°C. As weather changes from northwest to southwest, temperatures can drop by 20°C in 30 minutes although the mean annual range is only 10°C (McGann 1983). Katabatic drainage of cold air from the Port Hills into surrounding low lying areas can produce temperature gradients between these areas and the hills. Temperatures on frosty nights between 3 to 5°C higher on the hills than the plains are cited by Laing (1918) in Boyce (1939).

3.4 Ecological History of the Area

During the Governors Bay Volcanics period of history commencing c.15 million years ago, long periods of relative inactivity (around 1000 years) ensured that soil development and vegetation of significant areas of Banks Peninsula occurred. Baked soil and fossil records of Miocene floras are evidence that vegetation including podocarps, broadleaves, beeches and ferns were present and subsequently overwhelmed. This process of re-vegetation continued throughout the volcanic period with vegetation persisting into the recent glacial period of the last 2 million years (Wilson 1992).

Cooler temperatures during recent glacial periods probably resulted in the retreating of podocarp and hardwood species to refugia of sheltered coastal valleys and slopes and the expansion of subalpine flora like *Dracophyllum* and snow tussock. Re-colonisation by warm temperate species like kawakawa, akeake, titioki and shining broadleaf may have occurred repeatedly during inter-glacial periods and as recently as 14 000 years ago. As temperatures warmed again subalpine vegetation retreated and podocarp broadleaved forest re-colonised significant areas (Wilson 1992; McGlone 1983).

The Pleistocene Period was also the time that beech became established on Banks Peninsula. Glacial outwash and retreating sea levels provided the land bridge necessary for beech dispersal into this environment. The cooler temperatures aided beech establishment through competitive

advantage over podocarp/broadleaved forest in this climate. Recent warming of the climate over the last 14 000 years has resulted in the restriction of beech to the wettest and coolest areas of Banks Peninsula (Wilson 1992; McGlone 1983).

These accounts are supported by Holloway (1961) who reports the presence of mixed podocarp forest over the majority of Banks Peninsula prior to human arrival. Forest comprising abundant very large matai, totara and kahikatea with few rimu or miro was dominant. The understorey was largely made up of broadleaved species including broadleaf, mahoe, ngaio and pigeonwood with few podocarp seedlings present. This lowland forest type was typical of coastal lowlands in the North and South Island (Nicholls 1983). Ogilvie (1978) describes how a small area of this mixed podocarp forest type remained in the Hoon Hay basin up to the 1860s but was largely burnt out by a fire in 1868.

The arrival of Polynesian settlers to New Zealand around 1000 years ago coincides with minor increases in charcoal and bracken spores between 1000 to 800 years ago (McGlone 1983; McGlone 1989; Wilson 1992). The use of fire increased dramatically around 750 years ago as forest clearance escalated in response to increasing population demands and expansion. Drier eastern areas suffered the most from the use of fire with inland conifer forests and matai-totara forests greatly reduced (McGlone 1989). Estimates from one third to a half of pre human forest cover may have been destroyed before the arrival of European settlers (Wilson 1992; Wardle 1984).

The role of early Polynesians in the modification of vegetation by fire along the east coast of the South Island is described by Johnston (1961) as largely accidental and it was not until the European settlers arrived that Banks Peninsula forests were targeted for timber, firewood and grazing land. A mixture of milling and accidental and deliberate fires resulted in the destruction of most of the Banks Peninsula forest cover by c.1900. Pasture grasses, namely cocksfoot, were surface sown to replace the forest cover and exploit enhanced fertility following burning. As fertility decreased exotic weeds became established and still remain today.

The majority of matai-totara/broadleaved forests along north facing slopes of the Port Hills succumbed initially to Polynesian fire before the arrival of European settlers. Tussock grassland would have been dominant with some podocarp/broadleaved remnants and second growth kanuka

forest present (Williams 1992). Ogilvie (1978) relates the purchase of land stretching from Huntsbury Hill to Worsleys Spur Road by Sir John Cracroft Wilson in 1870 for farming suggesting the area had relatively little forest cover. The native tussock areas were oversown with exotic grasses to produce the mixed tussock grassland present today.

3.5 Today's Vegetation Cover

3.5.1 Port Hills

The prevalence of mixed tussock grassland is still a feature of the vegetation cover of the Port Hills today. This vegetation cover is dominant in exposed areas like ridge tops and shoulders and on north facing slopes. The uneconomic return from grazing due to reduced fertility and high costs of weed control has seen some areas of the Port Hills come under native restoration. Artificial restoration has concentrated in park areas including valley sides and bottoms with a range of broadleaved species typical to the historical Port Hills environment. Native regeneration is also occurring in areas like Hoon Hay Valley where regeneration is dominated by second growth broadleaved forest and exotic shrubland (Dugan *et al.* 2001). Exotic shrubland comprising invasive weeds like gorse and broom colonises and thrives in extensive areas of the modern day Port Hills environment. Established stands of these exotic weeds can provide a nurse crop for wind and bird dispersed native species facilitating native regeneration and eventual overtopping of weed species (Williams 1983; Wilson 1994).

CUC (1986) describe four broad vegetation types found in the modern day Port Hills environment including grassland, shrubland, forest and rock associations. Of these the predominant vegetation type of Banks Peninsula and the Port Hills is grassland.

- Short tussock grassland associations are characterised by silver tussock and danthonia interspersed with introduced grasses cocksfoot, sweet vernal, browntop and rye grass.
- Shrubland communities comprise broom and gorse invasions of grassland and native communities of bracken, *Coprosma* spp. matagouri, kanuka, koromikos and flax (CUC 1986).

- A small number of native forest remnants are present on the Port Hills today with most of these dominated by broadleaved associations of kanuka, kowhai, broadleaf, five finger, *Olearia* spp. *Pittosporum* spp, *Pseudopanax* spp.
- Exotic forest is largely restricted to the area between Dyers Pass Road and Gebbies Pass comprising mainly radiata pine with some macrocarpa and Douglas fir.
- Rock associations are found around bluffs and rock outcrops and typically host plants of the shrubland community together with porcupine shrub, dwarf kowhai and the Banks Peninsula hebe as well as a selection of herbs and ferns.

3.5.2 Cashmere Forest

The initial removal of native forest from the general area of Cashmere Forest by Polynesian induced fire is supported by purchase of this land for the purpose of grazing around 1870 (Ogilvie 1978). Boyce (1939) describes grassland as the dominant vegetation type in Cashmere Valley with bracken and gorse and broom also occupying significant areas. Historic management of these areas predominantly entailed grazing with sheep and cattle and burning which resulted in greatly restricting most of the remaining native secondary broadleaved species. Underground rhizomes in bracken and fast regeneration by broom allowed both these species to exploit the burning regime (Williams 1983). Market gardens and cultivated fields are reported on the lower slopes of Cashmere Valley while pockets of native bush exist in south facing niches where broadleaf, mahoe, *Corokia cotoneaster* and ngaio are present (Boyce 1939). Tree and shrub species like cabbage tree, scrub pohuehue, pohuehue, matagouri, bush lawyer, native broom, tree fuchsia, *Hebe salicifolia*, mahoe, flax, *Sophora microphylla*, *Sophora prostrata*, *Coprosma* spp., and herbs and grasses like *Acaena* spp., *Carex* spp. and *Poa* spp. are also listed as present in Cashmere Valley around this time.

Grazing and burning may have continued in this area until establishment of the current plantation forest began around 1980. Today, exotic plantation forest is the dominant vegetation type of Cashmere Forest and will be addressed fully in the following chapter. Areas within Cashmere Forest where plantation forest is not present amount to c.43 ha or around 11% of the total area. These areas are described as tracks, clearings or bluffs may have plantation species present but they are not the dominant vegetation type.

Track areas appear along established tracks and include adjacent clearings that have not been planted in production forest. Clearings are typically areas of production forest that have not been established in original operations due to issues around access, exposure or poor survival of plantation species. Bluffs are relatively large areas of exposed volcanic bedrock sometimes in association with small clearings. Within each of these areas there may be up to three broad vegetation types including tussock grassland, mixed shrubland and/or rock associations (Figure 3.4). A further vegetation type found in riparian areas is not shown below and largely exists beneath the plantation forest canopy. Broad descriptions of indigenous plants within each vegetation type follow below with specific plants lists for each non plantation area are supplied in Appendix 3.

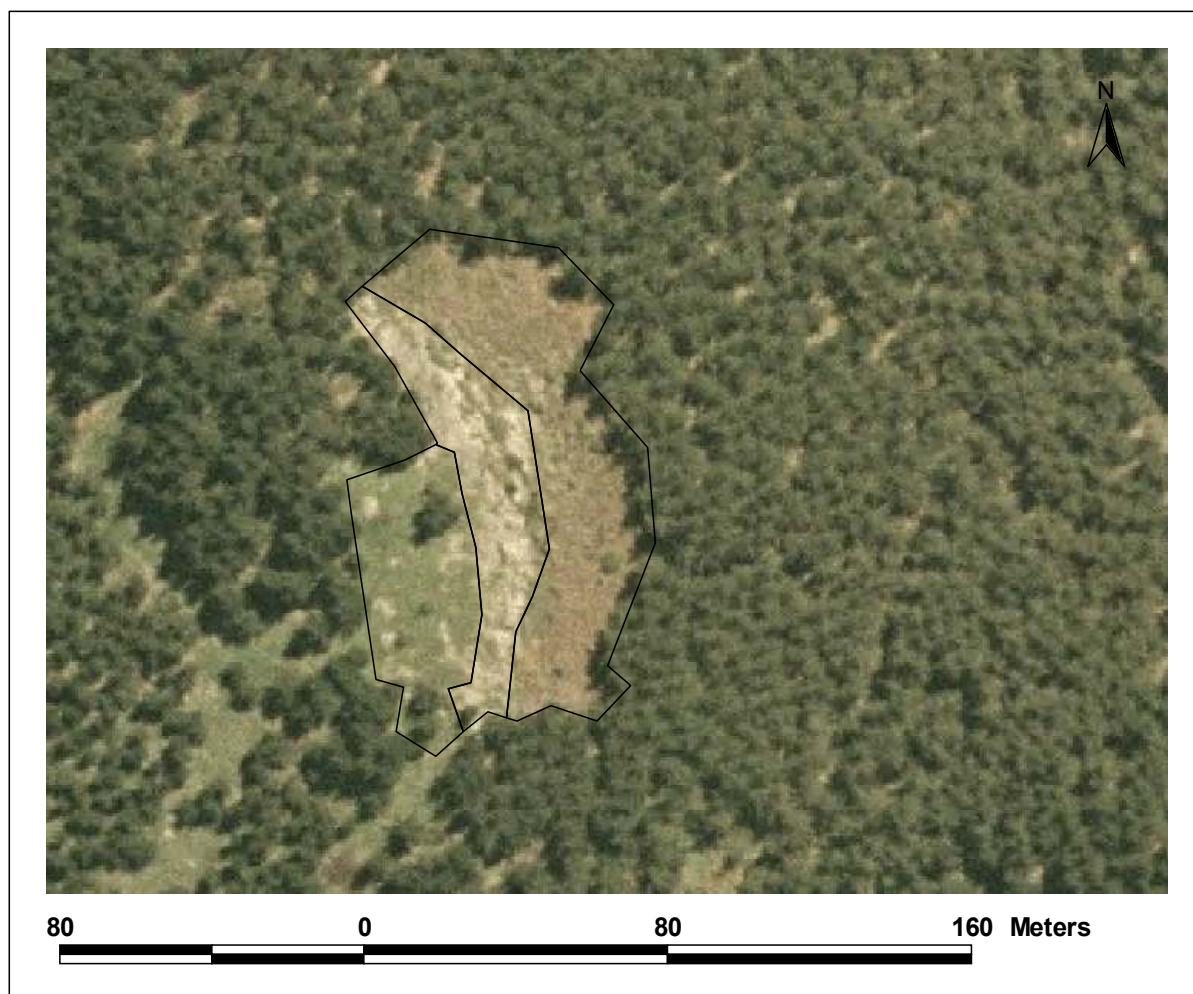


Figure 3.4: An example of three different vegetation types (Tussock grassland, Rock association and Mixed shrubland) occurring from left to right in one bluff area of Cashmere Forest.

Tussock grassland

Tussock grassland is a common non plantation vegetation type in Cashmere Forest. It is commonly found on tracks and clearings in the exotic forest where it often exists in associations with mixed shrubland and rock associations. Tussock grassland is characterised by the native grass silver tussock and exotic grasses cocksfoot, brown top and sweet vernal. A mixture of native and exotic herbs are commonly found in this vegetation type including, red bidibid, yellow oxalis, white clover, yarrow, foxglove, cleavers and vetch.

Mixed shrubland

Mixed shrubland is a less common vegetation type than tussock grassland and is often found as a component of, or in close proximity to tussock grassland. When mixed shrubland exists in this environment it is often on rocky, sloping and/or south facing areas. Areas of mixed shrubland are also closely linked to rock associations. Mixed shrubland is characterised by a mixture of native and exotic species. In dry north facing habitats matagouri, scrub pohuehue, broom and gorse dominate while in other more sheltered areas species like bracken, south island kowhai, dwarf kowhai, karamu, flax, small leaved *Coprosma spp.*, poroporo, mahoe, tree fuschia, flowering currant and elderberry also occur.

Rock associations

Rock associations are commonly found on rock outcrops and bluffs. If they occur in a forest canopy gap that exceeds the area of rock association then tussock grassland or mixed shrubland will also occur. Rock associations are typically dominated by native shrubs and herbs with some exotic shrubs and herbs also present. Native species inherent to rock associations include dwarf kowhai, mahoe, small leaved coprosmas, porcupine shrub, matagouri, scrub pohuehue, cabbage tree, common shield fern, round leaved fern, necklace fern, New Zealand linen flax, New Zealand iris and Banks Peninsula hebe. Exotic species include sorrel, cats ear, cleavers, broom, cocksfoot, sweet vernal and brown top, fireweed, white clover and vetch.

Riparian

Most of the streams within Cashmere Forest only run following significant rainfall or in winter and as a result riparian vegetation extends into stream beds. Riparian areas (including stream beds, banks and adjacent perimeters) mostly occur under the exotic plantation canopy. The relatively moist nature of the riparian areas and the predominance of shaded environments

provides habitat for some additional species not typically found in other vegetation types. These species include *Hypolepis ambigua*, swamp sedge, native jasmine and broadleaf. A wide range of exotic species are present within this vegetation type including, male fern, old mans beard, blackberry, elderberry, flowering currant, foxglove, hemlock, and fennel, these species can dominate indigenous vegetation where the production canopy is not present.

In general, indigenous biodiversity increases as stream elevation decreases and capacity increases. Indigenous biodiversity is also notably greater in streams that are on the east side of Cashmere Forest and under the production canopy. East side streams have increased flow originating from Dyers Pass Road and are generally south facing resulting in shelter from drying northwest winds and increased soil moisture. The past establishment of plantation species throughout riparian areas will result in these areas coming under harvest operations at some time in the future. Following harvest, riparian areas will however be extended and exclusively restored with indigenous species.

Plantation Forest

There are several indigenous species which inhabit the understorey of the plantation forest. The number of species identified increases in small canopy openings, stream beds and on southerly facing slopes. The most prevalent indigenous species under the canopy are necklace fern, common shield fern, poroporo and scrub pohuehue, bracken, karo, mahoe and karamu. Most of the shrub species occur as seedlings or small plants. Grazing is very evident on mahoe seen in the understorey.

3.6 Fauna

The proximity of Banks Peninsula to the South Island, New Zealand ensured that a common faunal gene pool existed between these two areas. This duplicity would have persisted until the time of human settlement around 1000 years ago (Wilson 1992). The arrival of Polynesians at this time resulted in the extermination of several bird species through the introduction of Polynesian rats and dogs, hunting and habitat destruction. Among those species to go extinct following Polynesian settlement were several species of moa, adzebill, flightless geese, swans, a

giant eagle, a giant rail, pelicans and an owl-nightjar. The millennia of evolution of flightless birds in New Zealand left these species unprepared for the sudden introduction of predators.

The number of predator introductions and level of habitat destruction escalated markedly with the arrival of European settlers in the mid 1800s. Timber clearance for agriculture and significant fires in 1859 and 1862-63 denuded large areas of Banks Peninsula with consequent reductions in the number of bird species (Turbott 1969). Habitat reduction from large fires and the introduction of cats, dogs and rats around 1860-80 and mustelids in 1880 resulted in two periods of local extinctions between 1870 and c.1900. Piopio, SI Kokako, S I Saddleback, NZ Quail, Laughing Owl, robin kaka, yellowhead and two species of parakeet all became locally extinct at this time.

Upon the settlement of Christchurch by Europeans 31 species of native birds were recorded as occurring on the Port Hills. This number increased to 32 in July 1856 with the arrival of the Silvereye, a self colonist from Australia. Of those 32 native species, thirteen are presently known to occur along with 18 introduced species (Crossland 1996). Silvereye, Grey Warbler, Bellbird, SI Fantail, Shining Cuckoo and NZ Pigeon (Kereru) are the most common of the native forest birds with Harrier, Welcome Swallows and NZ Kingfisher the most common open country birds. Recently Crossland (2003) reported eight of these native bird species present in Cashmere Forest with the shining cuckoo not present but likely to be so. The native species include:

- Australasian Harrier *Circus approximans* – less common above all habitats
- New Zealand Kingfisher *Halcyon sancta* - less common in forest edge and clearings
- Welcome Swallow *Hirundo tahitica* - less common above forest and scrub
- Kereru *Hemiphaga novaeseelandiae* - less common in forest and forest edge
- Grey Warbler *Gerygone igata* - common in pine forest and scrub
- South Island Fantail *Rhipidura fuliginosa* - common in pine forest and scrub
- Silvereye *Zosterops lateralis* – common in pine forest and scrub
- Bellbird *Anthornis melanura* – less common in Douglas fir forest, Radiata forest edge and regenerating native pockets.

- New Zealand Pipit *Anthus novaeseelandiae* - less common on rocky outcrops and short grass
- Shining Cuckoo *Chrysococcyx lucidus lucidus* (not seen but likely to be present)

Exotic species include:

- Blackbird *Turdus merula* - common in pine forest
- Song Thrush *Turdus philomelos* - less common in forest
- Dunnock *Prunella modularis* - common in pine forest and scrub
- Skylark *Alauda arvensis* - less common in grassland habitats
- House Sparrow *Passer domesticus* - less common in pine forest
- Chaffinch *Fringilla coelebs* - common in pine forest and scrub
- Redpoll *Carduelis flammea* - common in pine forest and scrub
- Goldfinch *Carduelis carduelis* – less common in pine forest and scrub
- Greenfinch *Carduelis chloris* - less common in pine forest and scrub
- Yellowhammer *Emberiza citrinella* - less common in scrub and forest edge
- Starling *Sturnus vulgaris* – less common in scrub, grass habitats and forest edge
- Magpie *Gymnorhina tibicen* - less common in pine forest, scrub and grass
- Rock Pigeon *Columba livia* - less common in forest edges
- California Quail *Callipepla californica* - less common in pine forest and scrub
- Little Owl *Athene noctua* (not seen but likely to be present)
- Cirl Bunting *Emberiza cirlus* (not seen but likely to be present)
- Pheasant *Pavo cristatus* (not seen but likely to be present)

Cashmere Forest plays an important role in linking adjacent habitats (Victoria Park and Hoon Hay Valley) providing nesting sites and as a consistent food source for these birds (Crossland 2003). No surveys have yet been undertaken on invertebrate fauna within Cashmere Forest although wetas and moths were commonly seen during forest inventory. There are several larger exotic fauna present in and around Cashmere Forest. Red deer, hares, rabbits, and a stoat/ferret

have been sighted within the forest while numerous possum trails are evident around the forest perimeter and shrub and grassland areas.

3.7 Streams

Cashmere Forest provides a significant catchment area for the Heathcote River through two tributaries of Cashmere Stream which extend to the upper reaches of the forest (Figure 3.5). These tributaries have several small side streams which provide drainage of upper slopes and Dyers Pass Road. These upper tributaries are predominantly dry during summer months but play an important role in storms for channelling flows (CUC 1986). CUC (1986) also outline the importance of Cashmere Valley floor for large scale stormwater storage. Streams on the east side of Cashmere Forest may have higher storm flows due to concentrated run-off from Dyers Pass Road. The increased level of native biodiversity along these streams supports this. There has been no survey undertaken of the fauna within any of the Cashmere Forest streams. There are several artificial dams within the forest that may have been originally constructed for stock watering purposes. Silt deposition and wall failure has rendered most of these structures ineffective.

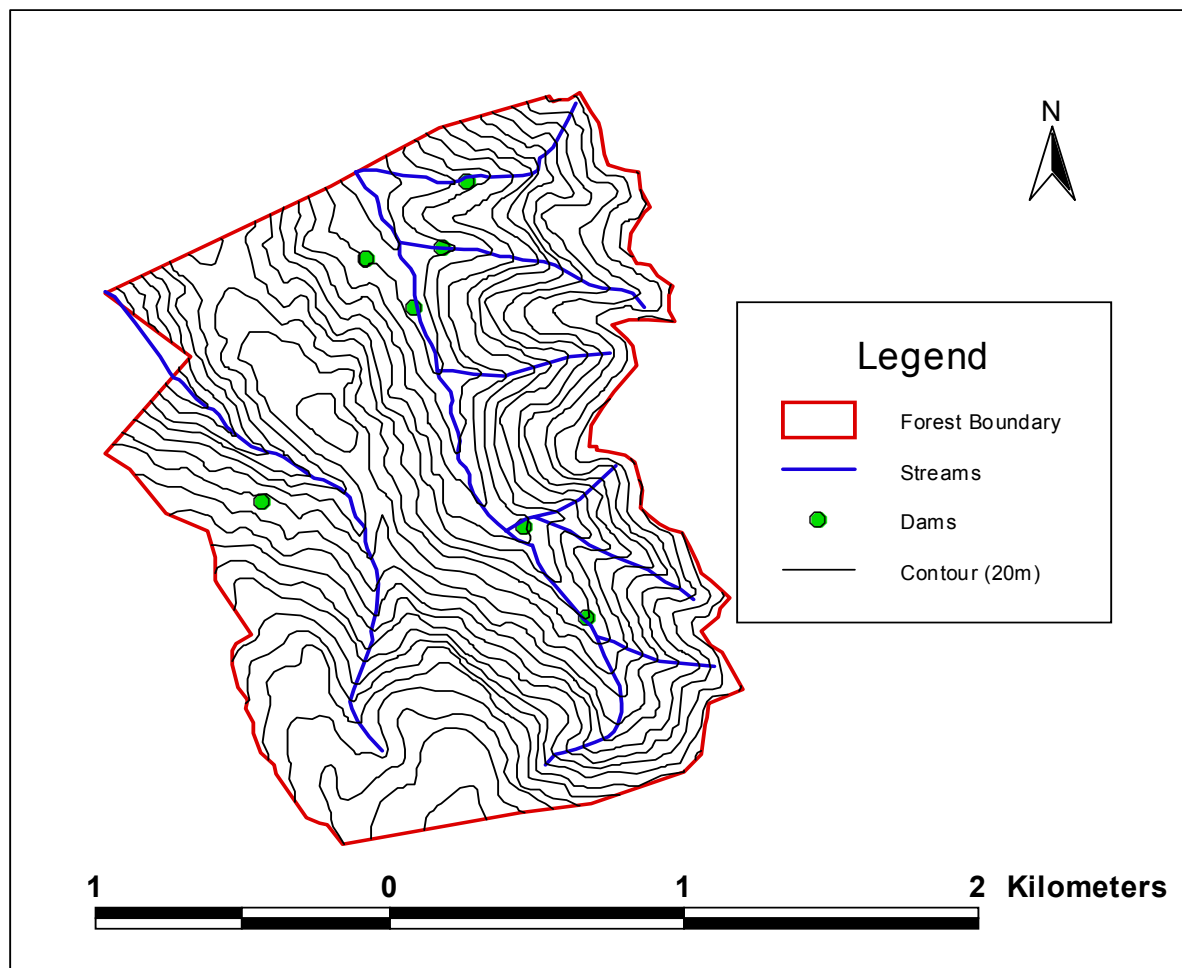


Figure 3.5: Water features present in Cashmere Forest.

3.8 Adjacent Areas

Cashmere Forest is bounded on three sides by areas of relatively high biodiversity for the Port Hills area (Figure 3.6). The forest occupies a significant chunk of landscape which provides connectivity between Victoria Park to the east, Hoon Hay Valley to the west and restoration areas to the south along the Summit Road. Victoria Park is currently comprised of areas of native restoration and exotic forest while Hoon Hay Valley has exotic forest, second growth bush and regenerating scrub. Extensive native restoration and diversification of plantation species within Cashmere Forest aims to facilitate the movement of native fauna and consequently flora between these sites and Cashmere Forest.

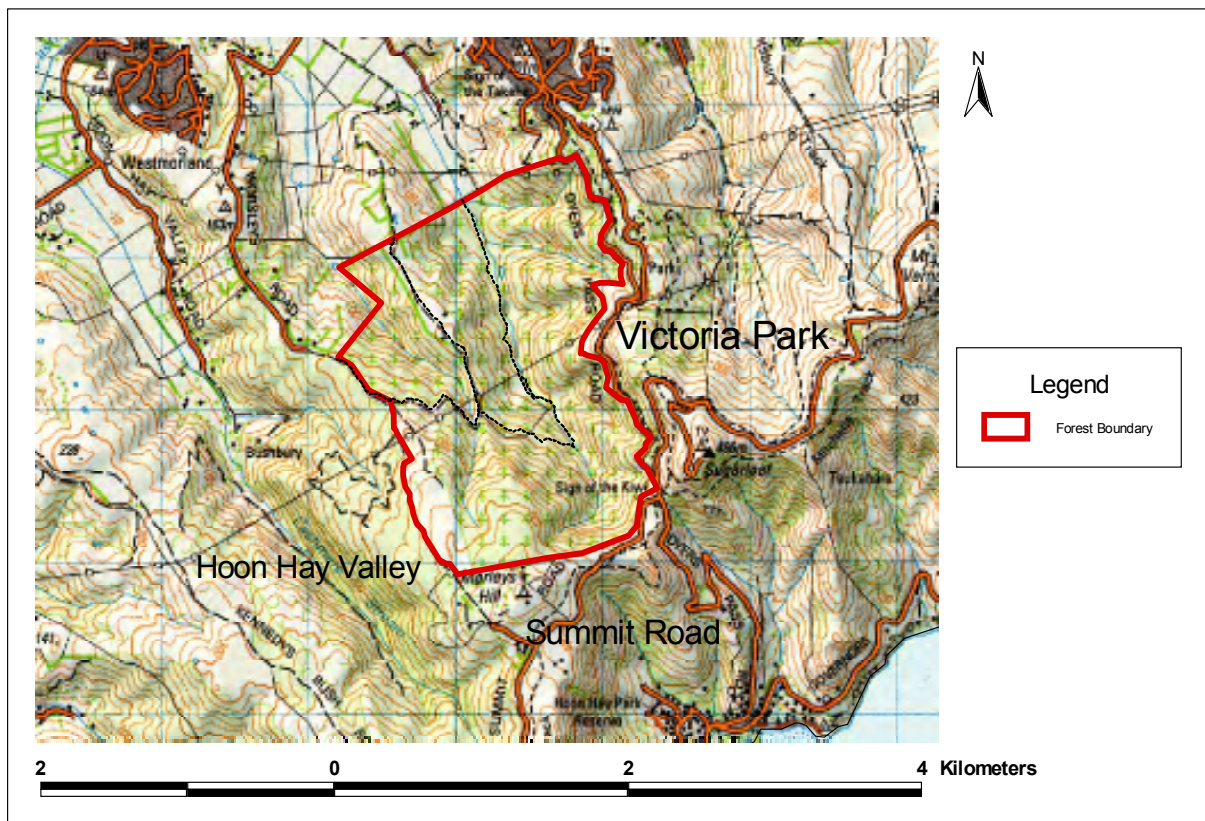


Figure 3.6: Indigenous restoration and park areas adjacent to Cashmere Forest.

Chapter 4

Production Forest Description

4.1 Introduction

The plantation component of Cashmere Forest was established as a production forest by the McVicars Timber Group Ltd. The initial forest establishment was carried out on what was formerly farmland from 1979 through to 1994. Further re-establishment has been undertaken to restock areas that have succumbed to wind and snow damage from 1995 to 2000. The production forest is currently planted in predominantly radiata pine (*Pinus radiata*) (94%) with the remainder planted in Douglas fir (*Pseudotsuga menziesii*) occupying around 89.5% of the total Cashmere Forest area; remaining areas are designated as non plantation areas and include tracks, clearings and bluffs. The production forest description covers issues surrounding the land, the forest, forest regulatory limitations and social and environmental factors.

4.2 Forest Context

4.2.1 Forest Boundary

The forest boundary lies within the legal land area of Cashmere Forest along most of the boundary line except in two locations (Figure 4.1). Firstly on the northern boundary where it extends around to 30 m past the legal boundary and secondly in the northwest corner where it extends up to 80 m past the legal boundary of Cashmere Forest. A possible resolution for this issue is to purchase the extra land from Graeme McVicar who is the adjacent landowner along the northern boundary. The forest area for valuation purposes has not included those forest areas outside the legal boundary.

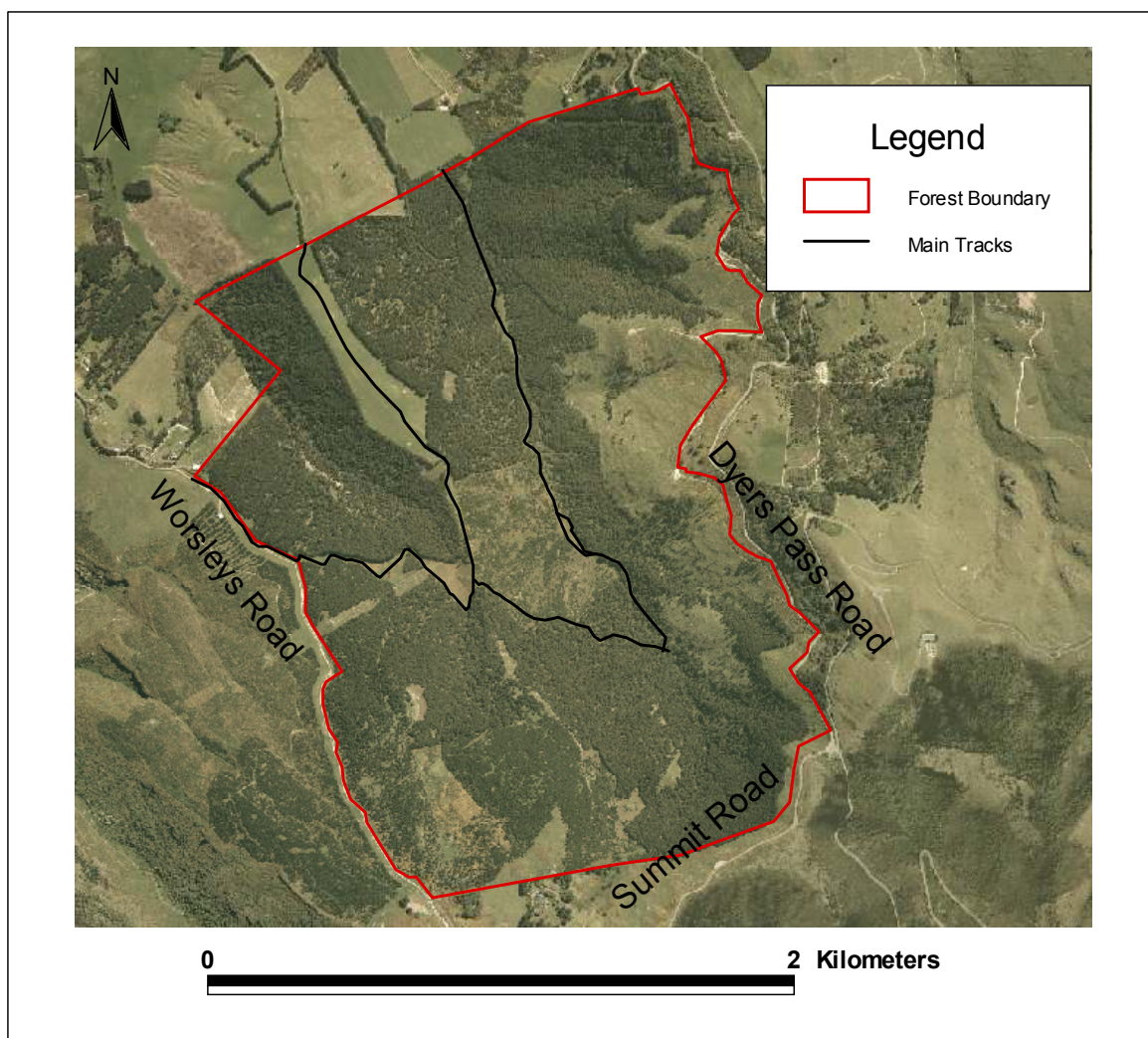


Figure 4.1: Cashmere Forest boundary and adjacent roads.

4.2.2 Forest Area

The total plantation forest area for Cashmere Forest is reported in Table 4.1 as 340.2 ha. This comprises 292.7 ha of sampled forest for the purpose of growth modelling and NPV calculations and 47.45 ha of younger unsampled forest. The residual area is comprised of non plantation areas which include bluffs, clearings and tracks (Figure 4.2). The proposed future area of plantation forest is around 222 ha, the reduction in plantation forest area reflects the long term forest vision (200 years) of replacing some plantation areas with native restoration.

Table 4.1: Compartment and strata information for the production component of Cashmere Forest.

Compartment Id	Area (ha)	Strata	Area (ha)	Planting Year	Treatment Age (years)		
					Low prune	Mid prune	Thinning
7901	5.614	1		1979	9	11	11
8102	3.577	1		1981	9	11	11
8003	0.829	1		1980	9	11	11
8004	29.303	1		1980	9	11	11
8001	6.459	1	45.78	1980	9	11	11
9401	22.504	2		1994			
9404	2.635	2		1994			
9701	14.817	2		1997			
9501	3.026	2	42.98	1995			
8101	38.122	3	38.12	1981	9	11	11
8901	36.29	4	36.29	1989	8	10	10
8002	16.869	5		1980	9	11	11
8201	2.106	5		1982	9	11	11
8002	6.688	5		1980	9	11	11
8201	0.684	5	26.35	1982	9	11	11
8603	6.391	6		1986	9	11	11
8602	8.481	6	14.87	1986	9	11	11
8601	19.499	7	19.50	1986	9	11	11
9101	12	8	12.00	1991	9	10	10
8203	13.9	9		1982	9	11	11
8202	14.168	9	28.07	1982	9	11	11
9403	12.11	10	12.11	1994	7		
8005	16.658	Dfir	16.66	1980			
Forest Area for NPV purposes			292.73				
2001	0.247	11		2000			
2002	38.78	11		2002			
2002	5.635	11	44.66	2002			
9402	2.789	Dfir	2.79	1994			
Total forest area			340.18				

The proposed construction of roads connecting residential and park development of Cashmere Forest to the bottom section of Worsleys Road will allow entry to the forests northern or bottom reaches. It is assumed all of these access alternatives are viable from discussions with the PHPTB project team.

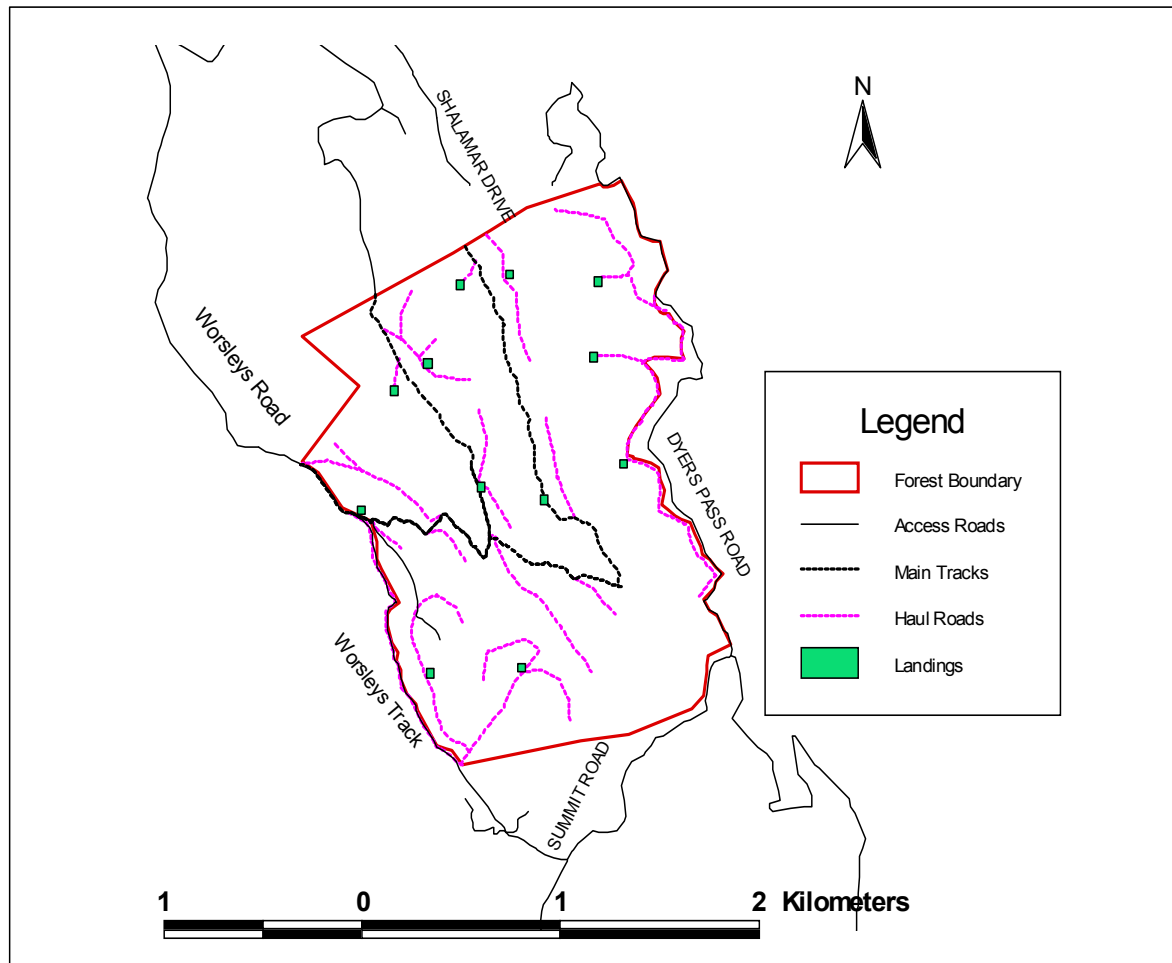


Figure 4.3: Access roads, main tracks and proposed haul roads and landing sites for Cashmere Forest.

Tracks

Significant upgrading of the main tracks (5.5 km) (Figure 4.3) within Cashmere Forest is required to allow access for forest harvesting and management while also facilitating public access and escape routes. The main tracks will require extending and augmenting with haul roads (12.9 km) as harvesting of compartments is scheduled.

4.2.4 Regulatory Limitations

Cashmere Forest lies within the Christchurch City boundary and forest management within it comes under administration of the Land and Vegetation Management Plan, Part II: Earthworks and Vegetation Clearance Port Hills (Canterbury Regional Council 1997). This plan is prepared under the Resource Management Act 1991 to address the management of earthworks and vegetation clearance in the Port Hills. Under the plan the Port Hills is split in to two areas defined as:

- Area i “land zoned for urban purposes in the Christchurch City and Banks Peninsula Transitional District Plans and land within 100m of land zoned urban; and”
- Area ii “rural land more than 100m from urban land”

The majority of Cashmere Forest falls into Area ii although there is one small area of Area i land in Title number 3 (Appendix 2). The proportions of land in Areas i and ii may change in the future as applications for residential development on adjacent properties and Cashmere Forest are possible. There are a range of Permitted and Discretionary activities outlined within the plan which are relevant to forestry management and operations and they are described in Appendix 4(Find reference). The draft “New Zealand Environmental Code of Practice for Plantation Forestry” (NZFOA 2006) will provide the framework for all forest management and should ensure that these activities comply with permitted and discretionary activities under district and regional plans.

4.2.5 Environmental Forest Benefits

Soil

Tall vegetation or forest cover plays a crucial role in reducing the risk of soil erosion and failure on steep hill country. The value of plantation forests in soil conservation has long been recognised in the Port Hills with plantings carried out under the Soil Conservation and Rivers Control Amendment Act 1941, administered by the North Canterbury Catchment Board (CUC 1986). O’Loughlin (2005) highlights some of the advantages resulting from forest cover including:

- depleting soil moisture by evapotranspiration so that soils take longer to reach saturation where substantial runoff starts to occur;
- providing a permeable forest floor organic layer to reduce rain impact and allow throughfall to percolate into the soil. The organic layer also acts as a water storage device;
- mechanically reinforce the soil with roots by:
 - bonding soil layers and sub strata vertically;
 - creating a lateral soil root mantle in the top 50 to 100 cm which holds lower layers in place and protects upper layers from erosion, especially in close proximity to the tree stump.

Some disadvantages of plantation forest cover pointed out by O'Loughlin (2005) and Environment Canterbury (Ecan) (2001) include;

- the weight of the forest increasing downslope pressures and creep in some soils;
- the exposure of soil beneath the root plate to erosion following windthrow;
- a period of high risk around the time of harvesting; and
- tunnel gullies initiating down decayed tree roots.

The high erosion risk around the time of harvest is due to soil exposure following road construction and maintenance, and harvesting and extraction operations (Megahan & Kidd 1972; O'Loughlin 2005). Employing management scenarios that minimise these operations and ensuring best management practice during their implementation will reduce erosion risk.

Water

The relationship between tall vegetation or forest cover and water yield is dynamic and largely determined by the nature (intensity and duration) of precipitation (Fahey 1964). Davie & Fahey (2005) report the largest impact of forest cover on total water yield is the increase in evaporation of intercepted rainfall due to the large canopy area of this vegetation type. The increase in evaporation results in a direct decrease in the amount of water available for runoff and streamflow and consequently total water yield.

Forest cover also reduces peak flows for small storm events and to a lesser extent for large storm events, largely due to increased interception and lower soil moisture under forest cover (Davie & Fahey 2005). Seasonal timing is important as soils under forest cover take longer to recharge to saturation point than pasture following a drying period. As rainfall increases in autumn and winter forest soils retain more capacity for absorption of peak flows than shorter vegetation types like pasture which recharge quicker. Once the soil has reached saturation point under forest cover and canopy evaporation is not occurring then peak flows will be similar to those from shorter vegetation types.

4.2.6 Social Forest Benefits

Landscape

The forest cover within Cashmere Forest is an essential component of the integral backdrop the Port Hills provide to the city of Christchurch. Forest management practices aimed at preserving this landscape and minimising harvesting impacts while retaining financial viability are a primary goal of this management plan.

Recreation

The plantation component of Cashmere Forest creates an additional recreational opportunity for the people of Christchurch city. Forest infrastructure will be available for recreational use outside of operational periods. Infrastructure will facilitate access and the extension of the recreational track network while forest management operations will be planned to minimise disruption to recreational users. Plantation forests also offer alternative biodiversity and environmental values to recreational users that are otherwise limited in the Port Hills.

4.3 Forest Description

4.3.1 Compartment Area

Initial descriptions, areas and boundaries for forest compartments were obtained from PHPTB (2004) in the “Options for future use of Cashmere Forest Park” document. These details of area and boundary lines were then updated using recent GIS images sourced from Terralink New Zealand and by ground truthing using GPS points created along actual compartment boundaries.

4.3.2 Forest Inventory

The forest inventory was carried out at relatively high intensity of 2.2% of forest area in order to counter the paucity of earlier growth information for the forest. Systematic sampling was chosen as a sampling technique to allow fast plot establishment and efficient forest coverage. Bounded circular plots were spaced out at c.100 m intervals along appropriate compass bearings (Figure 4.4). Within each plot DBH and Method for Assessment of Recoverable Volume by Log type (MARVL) cruising information was recorded for each tree and tree height was measured for at least 50% of trees.

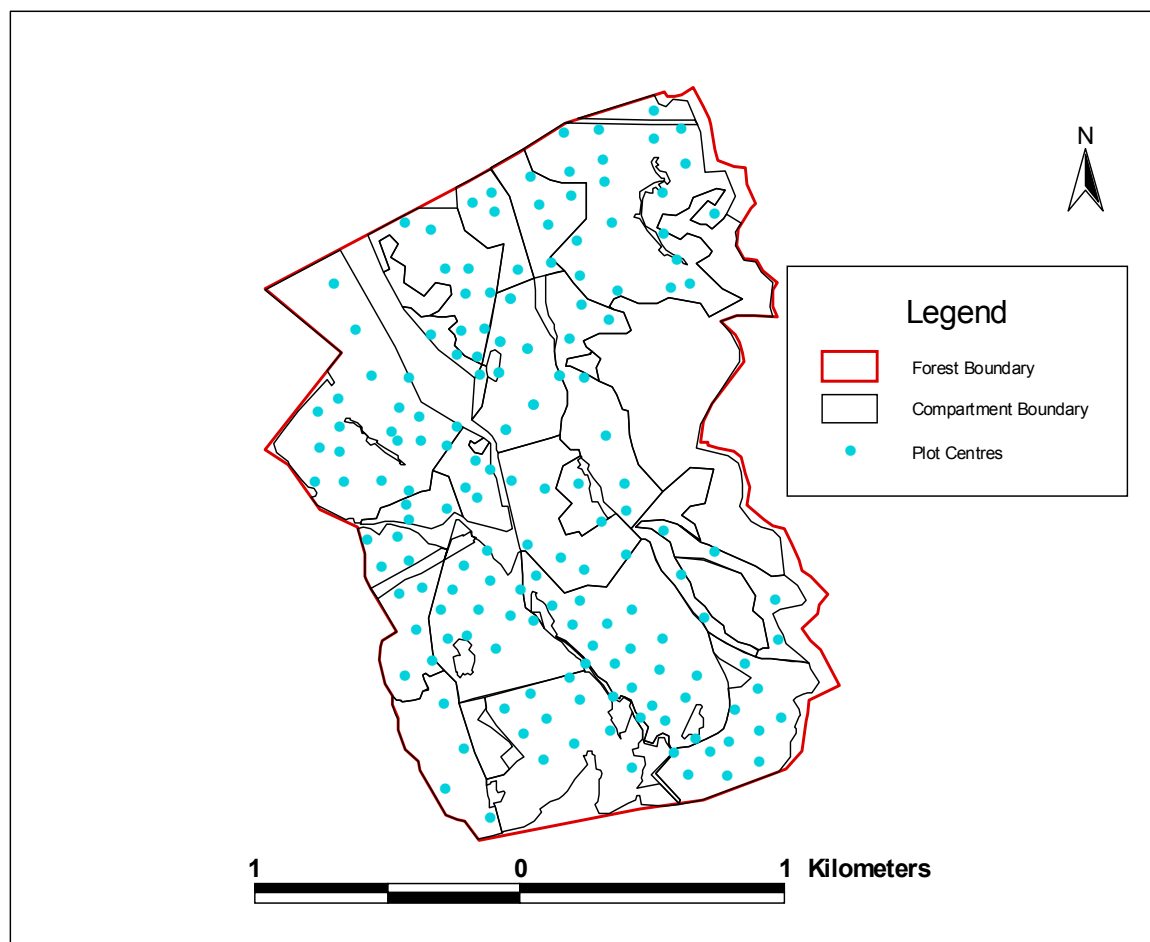


Figure 4.4: Location of inventory plots completed in the summer of 2005/2006 in Cashmere Forest.

4.3.3 Compartment History

The silvicultural history of each compartment is displayed in Table 4.1. The information in Table 4.1¹ does not describe high pruning that occurred in compartments 8101, 8602 and 8603, nor does it state initial stocking, thinning intensity or pruned height. The unavailability of this information and past inventory work has placed limitations on the validity of growth model allocation to this forest. The first establishments of radiata pine and Douglas fir began in 1979 and 1980 with further plantings continuing until 1994. Significant wind and snow damage has required restocking of around 18% of the forest area (1995 to 2002). All compartments are stocked with radiata pine unless otherwise stated in the stratum column.

¹ McVicars Timber Group Ltd, Email

4.3.4 Stratum Description

Forest stratification is a common practice in forest management and facilitates the aggregation of forest data for similar compartments to aid and reduce analysis. Decisions on forest strata considered stand statistics i.e. age, basal area, mean top height and stocking which were supported by visual assessments of factors like pruned height during forest sampling. Stratum allocation is reported in Table 4.1 and stratum statistics derived from growth models operating within MARVL are outlined in Table 4.2. Several compartments were significantly different to any other compartment through differences in age, treatment history or the effects of other environmental conditions and therefore were stratified singly. The implementation of one silviculture and management regime for future establishment should realise a reduction in the number of forest stratum.

Table 4.2: Stratum statistics for the production component of Cashmere Forest.

	Area	Age	Volume	Mean Top	Basal Area	Mean	Stocking
Stratum	(ha)	(years)	(m3/ha)	Height (m)	(m2/ha)	DBH	(sph)
1	45.78	26	432.82	30.82	45.58	411	343
2	42.98	12	155.54	13.50	13.83	212	885
3	38.14	25	413.34	29.67	43.01	382	375
4	36.29	17	315.57	21.95	44.00	278	722
5	26.35	26	459.30	27.53	51.70	363	500
6	14.89	20	403.55	30.75	39.92	454	246
7	19.49	20	348.07	23.22	45.44	378	404
8	12.04	15	273.56	18.85	42.41	332	489
9	28.07	24	367.00	27.34	42.14	375	381
10	12.13	12	92.93	13.07	20.12	275	338
Dfir	16.66	26	267.21	19.60	40.74	282	652
Total	292.8						

Chapter 5

Approach to Economic Evaluation

5.1 Introduction

This section outlines the decision making and information upon which the economic evaluation was undertaken. A considerable amount of information is required before an economic evaluation can proceed; this information must be accurate, current, applicable, and relevant. Forest information for Cashmere Forest was collected during a c.2% MARVL inventory over the 2005/2006 summer. Cost and revenue information was collated (Feb 2006) from local forestry companies, forestry publications and contractors and then adjusted where necessary, for conditions in Cashmere Forest. This information was used in conjunction with output from MARVL software which identified yields and revenues associated with a range of future harvest dates and systems.

5.2 Cost Information

5.2.1 Harvesting

Harvesting in Cashmere Forest will be a unique operation that aims to employ a range of harvesting systems in a Forest Park environment. This environment will encompass several constraints including:

- high public visibility;
- recreational users;
- stringent environmental goals;
- coupe harvesting;
- Continuous Canopy Management (CCM) ; and
- steep terrain.

These constraints will result in additional cost for harvesting operations. Therefore, all estimates on harvesting costs have received an added premium depending on the type of operation and likely terrain.

Harvesting cost information for ground based operations was provided by two local forestry companies, SPBL¹ and Rayonier². Rayonier also supplied cost information for cable harvesting and estimates on likely premiums necessary for coupe harvesting. Price information was based on an average piece size of 2 m³ to which a premium was added. An existing model ($y = a + (b / x)$) describing the relationship between harvest cost and piece size was then applied to prices to come up with a suitable range for Cashmere Forest. Indicative harvest prices are outlined in Table 5.1.

Table 5.1: Price estimates for harvesting operations in Cashmere Forest.

Harvest System	Harvest Regime		
	Clearcut	Coupe	CCM
GB*	\$23.98	\$26.09	\$29.98
Cable*	\$32.01	\$34.07	
* Average Piece Size of 2 m ³			

An alternative cost option for harvesting in CCM exists³ however it was not utilised in this analysis as it incorporates an hourly rate which is inconsistent with the other two cost regimes. An hourly rate would facilitate careful logging practice and reduce residual damage to the remaining stand; both of which are important in CCM. An hourly rate for two bushmen and a skidder of around \$150 per hour is currently acceptable in a local operation, however different conditions in Cashmere Forest may result in an increase of this rate.

5.2.2 Haulage

The central location of Cashmere Forest results in relatively minimal haulage charges for forest products. Haulage costs were based on taking export logs to Lyttleton, saw logs to Harewood (McVicars Timber), and pulp logs to the pulp mill at Rangiora. Lyttleton and Harewood are both between 20 to 25 km from Cashmere Forest and Rangiora is between 45 & 50 km. Indicative

¹ Hurford, L. Sales and Operations Manager, SPBL, Darfield, Canterbury. 8/03/2006. Interview.

² Grover, M. Production Manager, Rayonier, Rangiora, Canterbury. 9/03/2006. Interview.

³ Wardle, J. Owner and manager of Woodside Forest. 25/04/2006. Interview.

haulage or haulage charges were received from local forestry companies, SPBL and Rayonier and then adjusted to suit Cashmere Forest (Table 5.2). Adjustments are generally a premium which reflects the smaller and inconsistent operations characteristic to Cashmere Forest.

Table 5.2: Price estimates for haulage of forest products from Cashmere Forest.

Km	(\$/T)
5-10	4.00
10-15	4.80
15-20	5.40
20-25	6.00
25-30	6.65
30-35	7.35
35-40	7.90
40-45	8.50
45-50	9.10

5.2.3 Earthworks

There are extensive earthworks to be completed within Cashmere Forest over the initial years of management. The majority of this work will be expensive as it is generally on steep terrain, has areas of exposed bedrock and some areas will require culverts. A local construction contractor¹ provided indicative prices for road building on a range of terrain, and prices for two culvert sizes; these were then applied to Cashmere Forest.

Earthwork in Cashmere Forest ranges from upgrading established tracks to creating new tracks from scratch. Establishing tracks from scratch on the steepest terrain was priced at \$50 000 per km, this is opposed to a price of \$10 000 per km for upgrading of an established track on easy terrain. A 300mm diameter, 5m wide culvert was priced at \$300 and a 1 000mm diameter, 6m wide culvert was priced at \$4 000 (this price includes headwalls). The 1 000mm culverts were used for all crossings of Cashmere Stream and the 300mm culverts were used on side tributaries. The 300mm culverts were also used for cross drains at regular spacing which was primarily dictated by terrain. The price for establishing a landing was estimated at \$4 000². All proposed haul roads aim to minimise stream crossings and maintain a gradient of less than 16°.

¹ Calcon, Canterbury. 25/03/2006. Phone Call.

² Springford, O. Registered Forest Consultant. 10/03/2006. Interview.

The total cost of constructing the main access track (\$248 507) is incorporated in all cashflow analyses in year one. Early construction of the main access track is seen as a crucial to facilitate good access and escape routes for all forest users. The cost of haul roads and landings are attributed to the stratum/strata for which the haul road/landing is providing harvest access. All roads and landings are to be constructed one year prior to the onset of operational use; this will be reflected in the timing of cost incursion in cashflow analysis. When coupe harvesting occurs, the cost of haul road construction is shared over the first two harvest visits.

5.2.4 Silviculture

Initial prices for silviculture operations were received from local forestry company, Rayonier¹ and a local forestry contractor, Nova Sylva Forestry.² These prices were then adjusted where necessary for Cashmere Forest (Table 5.3). Most adjustments resulted in adding a premium for performing operations in coupe or CCM conditions where areas are discontinuous and some walking between areas will be necessary. These costs are also likely to increase with the advent of alternative species that require intensive pruning regimes to induce good initial form.

Costs for initial herbicide desiccation and releasing are based on aerial application of herbicide by helicopter. Helicopter application will be possible in small coupes (2 ha) but will be more expensive than larger areas. Significant supplies of fresh water are also required for aerial application; it is suggested that a water tanker may need to be hired for this purpose as no significant reserve of freshwater is nearby. Weed control costs are significantly reduced under CCM where conditions are less conducive to good weed growth.

¹ Rapley, S. District Forester, Rayonier, Rangiora, Canterbury. 15/03/2006. Email.

² Tapley, P. Owner, Nova Sylva Forestry NZ Ltd, 21/03/2006. Email.

Table 5.3: Indicative costs for silviculture operations in the radiata pine component of Cashmere Forest.

Treatment		Clearcut (1000 sph)	Coupe (1000 sph)	CCM
Seedlings	(\$/tree)	0.31	0.31	0.31
Planting	(\$/tree)	0.35	0.37	0.37
Pruning	(\$/tree)			
	1st lift	2	2.1	2.4
	2nd lift	1.8	1.89	2.16
	3rd lift	2.1	2.21	2.52
Thinning	(\$/ha)			
	1st thin	295	310	354
	2nd thin	330	347	396
Spraying	(\$/ha)			
	Initial	220	230	100
	Release	180	190	100

5.2.5 Annual Charges

Price estimates for annual charges were received from a number of sources including Simon Rapley at Rayonier, Christchurch City Council, SPBL and Bruce Manley¹. Annual charges usually include costs for things like administration, management, and insurance required in a normal forestry operation. In Cashmere Forest annual charges include:

- overheads (administrative management) (\$80, \$85 per ha depending on coupe or CCM);
- land rental (rates) (\$54.70 per ha);
- fire risk (\$5 per ha);
- biosecurity (\$100 per ha in year 1, \$20 per ha in subsequent years).

The cost of overheads includes road maintenance and was increased as coupe harvesting and CCM were implemented to reflect extra management required under these systems. Biosecurity is relatively expensive in the first year as the pest management strategy is implemented but reduces in the following years as biosecurity threats are decreased. The annual charge for land rental represents the opportunity cost of having the land in forestry; it is not a representation of actual land value.

¹ Manley, B. Associate Professor, 20/03/2006. Interview.

5.2.6 Indigenous Restoration

The cost of indigenous restoration was estimated at \$40 000 per ha¹²³. This price includes planting at 1.5 m centres using PB5 and RX90 and weed control. Seedlings have stakes and weed mats where necessary and will require haulage to the planting site.

5.3 Log Grade and Price Information

Log grades and prices for radiata pine and Douglas fir (Tables 4.4 & 4.5) were created from grades and prices sourced from the Ministry of Agriculture and Forestry⁴ (MAF), Agrifax,⁵ and local forestry operators. The prices stated are in New Zealand dollars per cubic metre and relate to stumpage value i.e. they are the value of the log in the forest, not including harvesting and haulage costs. Common practices for setting log prices for the purpose of economic evaluation in New Zealand utilise long run averages which reflect the long term nature of the forestry industry. Long run averages are weighted against current prices where the forest under valuation is near harvest (Manley 2003; NZIF 1999; Colley 2002; Cheung & Marsden 2002).

Long term averages (5 years) were created from MAF radiata pine prices; these were then checked against current Agrifax prices. The current Agrifax prices (February 2006) were around 18% lower than the MAF 5 year average whereas the prices in Table 5.4 are c.10% lower than the five year average. This was seen as an appropriate level of pricing for Cashmere Forest because it is comprised of a diverse mix of age classes with some areas ready for immediate harvest while other areas are relatively young.

Log grades are a reflection of current export and local grades. Douglas fir prices and grades (Table 5.5) are simpler and were sourced directly from forest owner SPBL⁶ and a local log buyer¹ whom commonly deal with Douglas fir.

¹Norton, D, A. Associate Professor, University of Canterbury, 03/06/2006. Interview.

² Carter, D. Park Ranger, Christchurch City Council, 21/03/2006. Email

³ Tapley, P. Owner, Nova Sylva Forestry NZ Ltd. 21/03/2006. Email

⁴ <http://www.maf.govt.nz/forestry/statistics/logprices/index.html>. 05/03/2006.

⁵ Manley, B. Associate Professor, University of Canterbury, 01/03/2006. Email.

⁶ Hurford, L. Sales and Operations Manager, SPBL, Darfield, Canterbury. 8/03/2006. Interview.

Table 5.4: Proposed log grades and prices for radiata pine in Cashmere Forest.

Log Grade	SED (mm)	Max Knot size (mm)	Length (m)	Sweep	Price (NZD/m3)
P1	400+	0	4	d/4	140
P2	350-399	0	4	d/4	115
S1	400+	70	3.6, 4.2, 4.8, 5.4, 6.0	d/4	90
S2	300-399	70	3.6, 4.2, 4.8, 5.4, 6.1	d/4	82
S3	200-299	70	3.6, 4.2, 4.8, 5.4, 6.2	d/4	67
A	300+	70-99	4, 8, 12	d/4	86
J	200-299	70-99	4, 8, 12	d/2	65
KI	260+	100-150	3.6, 5.4, 7.3, 11	d/2	55
Chip	100	No Limit	3.6-6.5	d/2	49
Firewood	50	No Limit	N/A	N/A	10

Table 5.5: Proposed log grades and prices for Douglas fir in Cashmere Forest.

Log Grade	SED (mm)	Max Knot size (mm)	Length (m)	Sweep	Price (NZD/m3)
DF 30	300 +	70	4	d/4	130
DF 20	200 +	70	4	d/4	100
Firewood	50	No Limit	N/A	N/A	60

5.4 Economic Evaluation

5.4.1 Introduction

An extensive economic evaluation was performed on inventory information from Cashmere Forest and likely future costs and revenues to determine estimates for forest value and likely cashflow over the next thirty years. A liquidation value was calculated initially to identify the value of Cashmere Forest today, discounted cashflows were used to identify the potential ongoing value of the forest and a normal cashflow was used to determine revenue and cost trends over the next thirty years. It should be noted that forest stratum returning negative values under

¹ Janet, D. Log Buyer, 10/03/2006. Phone Call.

liquidation, DCF or normal cashflow analysis are harvested and remain under management which is in keeping with good forestry practice.

5.4.2 Liquidation Value

The liquidation value is the result of an economic evaluation performed to determine the value of the whole forest if it was liquidated (cut down and sold) today. The liquidation value gives us a point of reference for future discounted cashflows and NPV analysis, and provides us with a breakeven discount rate. A breakeven discount rate is the rate that when applied to NPV analysis, results in a forest NPV equal to the liquidation value. It is implied that if the forest was operating at this discount rate then liquidation would be a more attractive financial option than continuing forest operations. A liquidation value would usually be determined with the current market log prices, however in this case liquidation is not foreseen to take place immediately and the use of log prices set for discounted cashflow maintains price consistency across all valuation techniques.

5.4.3 Discounted Cashflow

Forestry is a relatively long term industry in comparison to other primary industries in New Zealand like horticulture and agriculture (Colley 2002). The average rotation length for a radiata pine crop in New Zealand at present is around 28 years. Therefore, a method is required which facilitates the evaluation of costs and revenues accrued in the future, in to a dollar value today. Discounted cashflow does this by using an interest rate to discount back those future costs and revenues to provide a single figure for comparison with other industries or investment opportunities (Horgan 2005). Discounted cashflow is reported as currently the most popular practice for the valuation of forestry enterprises in New Zealand (Bigsby 2004; Liley 2000; NZIF 1999).

NPV analysis provides a monetary value useful for comparison with other investment opportunities. In order to do this properly, NPV analysis in Cashmere Forest assumes that the particular forestry regime under valuation will be carried on in perpetuity, under best management practice; this facilitates the comparison of regimes with varying rotation length and forest management. This is especially appropriate in Cashmere Forest where coupe harvesting

and CCM is compared to clearcut harvesting. A figure for land expectation value (LEV) is also provided for a clearfell regime. LEV excludes land rental and reflects the maximum level of investment in land to create a given rate of return i.e. a given discount rate.

5.4.4 Discount Rate

The means for selection of an appropriate discount rate for forest evaluation is not clear in the literature. Conventional methods that use historic transaction evidence are not foolproof in New Zealand where there is a shortage of these types of transactions (Manley 2003; Liley 2002; NZIF 1999; Colley 2002). Other methods include:

- an implied discount rate from the share price of forestry companies;
- the minimum market acceptable internal rate of return (IRR) observed in a range of forest projects;
- use of the Capital Asset Pricing Model (CAPM) and Weighted Average Cost of Capital (WACC) approaches;
- declared asset reporting rates.

For the purposes of this study a pre-tax discount rate of 9% was selected. This rate was selected as an average figure used by forest valuers in a survey of discount rates by Manley (2003).

Allowance for risk is not included in this discount rate; it is factored in to discounted and normal cashflows as an annual charge. Rates of 7% and 11% were also used for sensitivity analysis.

5.4.5 Normal Cashflow

A normal cashflow (i.e. there is no discount rate) is useful for evaluating cashflow and cost and revenue trends over a future period. Normal cashflows in this project are pre-tax and do not incorporate borrowing or investment interest for negative or positive cashflows. They represent likely cashflow of Cashmere Forest over the next thirty years.

5.4.6 Land Area

The land area subject to economic evaluation under this analysis is the component of Cashmere Forest that is currently under production forest (340.2 ha). This economic evaluation does not pertain to non plantation areas. DCF analysis only considers areas of radiata pine planted between 1979 and 1997 and areas of Douglas fir planted in 1980. Areas planted in 1994 (Douglas fir) and, 2000 and 2002 (radiata pine) are not merchantable and were not sampled in the forest inventory and are therefore not considered in DCF.

Normal cashflows include areas of radiata pine planted in 2000 and 2002 by attributing yields from stratum 1 which has yields closest to the average stratum yield. The area of Douglas fir planted in 1994 has not been included in any economic analysis for several reasons including:

- the area is relatively small (2.7 ha) and will have minimal effect on forest cashflows;
- it is an exposed site and survival and growth are not great;
- the fact that they were not sampled and yield predictions from the other Douglas fir area are unlikely to be similar.

5.4.7 Sensitivity Analysis

Sensitivity analyses are performed to identify undue effects on forest value due to changes in valuation variables like discount rate, log prices and costs. For this project, sensitivity analysis for discounted cashflows were performed on discount rate, log prices, harvest and haulage costs, clearcut harvest age and the type of growth model used. In normal cashflows sensitivity analysis was used to evaluate growth models, changes in cashflow arising from alterations in silviculture regime and additional costs like indigenous restoration.

5.5 *MARVL Analysis*

5.5.1 Introduction

The Method for Assessment of Recoverable Volume by Log type (MARVL) forestry inventory system (Deadman & Goulding 1979) is generally designed for pre-harvest inventory. MARVL uses a set of user defined codes which recognise stem characteristics like pruned height, sweep and branch size in a MARVL inventory which is then analysed in the MARVL software to create outturn by log type. MARVL uses regional growth models to also predict future outturn by log grade (Manley *et al.* 1987).

5.5.2 Dictionary

A dictionary is a set of coding instructions for characterising sections of a trees stem during a MARVL inventory. In the inventory process a tree stem is assessed from the stump up with heights and related codes representing significant changes in stem characteristics. For example a relatively straight stem pruned to 5 metres would be assigned a code of A to 5m if small branching occurred after this the code would change accordingly and reflect the height to which small branches extended.

Each dictionary code is assigned to a log grade within the MARVL software depending on the suitability of that code to each log grade. For instance an A code that is relatively straight and pruned is suitable for cutting into all grades whereas a lesser code that represented significant sweep and large branches may only be suitable for one log grade. This is the key function of the MARVL program where stems are coded strictly according to characteristics and then independently converted into log types by the MARVL software. The MARVL software uses log value to prioritise log production while also attempting to optimise the entire tree stem.

The dictionaries devised for radiata pine and Douglas fir in Cashmere Forest are relatively simple and aimed to provide basic information around pruned height, sweep and branch size

(Appendices 5 & 6). A simple dictionary was implemented because the inventory needed to be

reasonably fast and efficient as the whole forest (c.295 ha) was to be inventoried by one person over the 2005/2006 summer.

5.5.3 Models

The MARVL program uses regional and national models developed by FRI to describe stand growth, height, volume, taper and breakage. The models and tables selected for evaluating Cashmere Forest are seen in Table 5.6.

Table 5.6: Models and tables used within the MARVL program for Cashmere Forest.

Models	Radiata pine	Douglas fir
Growth	Cant.	SI Dfir (1990)
Height	Cant.	SI Dfir (1990)
Height Adjustment	General PSP	
Growth Adjustment		Dfir Early NZ (1997)
Tables		
Volume	All NZ D.Sawlog (1990)	Dfir Canterbury (1990)
Taper	All NZ D.Sawlog (1990)	Dfir Canterbury (1990)
Breakage	All NZ	Dfir Golden Downs

An alternative set of growth and yield models developed by Zhao (1999) were used to audit Cant. model predictions. These models show reduced residual error and improved prediction over the traditional Canterbury model by recognising the effect of altitude on basal area and height growth. The models developed by Zhao (1999) are currently used by SPBL for Radiata pine growth and yield prediction. The proportional difference between Cant. and Zhao's model predictions for total tree volume were applied directly to Cant. revenues as a simple of means of auditing cashflow.

5.5.4 Coupe Harvesting and CCM

Producing recoverable volumes for coupe harvesting of using MARVL was addressed by harvesting 20% of each stratum at any time over five entries. Removing a coupe area from the stratum should not significantly effect the growth of residual trees as stand conditions remain constant except around new edges. While target harvest ages were set at 25, 30, 35, 40 and 45

years, a desire to aggregate harvest dates to reduce operational activity results changing harvest ages in some stratum.

The predominance of relatively short term (< 30 years) rotations and clearfelling as normal forestry practice has resulted in limited modelling ability past 35 years or accommodation of alternative harvesting practices. Therefore, while predicting growth and yield to 45 years is c.10 years outside the range of data used to develop the Cant. set of growth and yield models (Lawrence 1988) this was done to gain some understanding of what volumes and revenue may be achievable under those time frames. The models developed by Zhao (1999) are also limited in age (3 to 30 years) but they incorporate the effect of altitude and result in more conservative predictions of future growth and yield. These conservative predictions are applied to discounted and normal cashflows as a form of sensitivity analysis.

5.5.5 CCM (log trace)

CCM is also a difficult concept to model in New Zealand where most models and software is developed for short rotation clearcut forestry. It is a challenge within current software to reflect the changing stand conditions that result from CCM where stocking is slowly reduced over the entire stratum. As large trees are removed smaller residuals will gain access to more resources, enabling increased growth.

Intensive manipulation of data within the MARVL program allows this process to take place on a small scale. Traditional use of MARVL relies on the entry of one DBH and height measurement from which all future predictions are made. This process will not accurately reflect the reduced competition apparent under CCM. Under CCM, stocking, DBH and height needs to be entered following each harvest entry so that increased growth resulting from reduced competition can be realised. These measurements are then grown forward. This process is achieved in MARVL software through a log trace function which produces DBH and height growth as output at desired future ages.

Two stratum (3 & 6) were selected that would be most suitable for initial CCM. Due to the intensive manipulation of data required in this process only one plot was selected from each

stratum. Plot selection was undertaken by selecting the plot which had stand statistics closest to the stratum mean. Harvest years for CCM were kept consistent with coupe harvesting to simplify evaluation.

Within each plot trees were selected for harvest on a diameter cutting limit that saw trees over 600 mm DBH selected for harvest. The largest trees were selected first with total removals not to exceed around 20% of plot basal area. Basal area removal was limited so as to minimise canopy openings and opportunities for wind throw. The basal area limit was difficult to adhere to in subsequent removals as no replacement trees were added to the plot area resulting in over prediction of removal by basal area. Due to this issue six harvest visits were required to remove all trees from the selected plots resulting in around 17% basal area removal per visit. All visits were encompassed in the existing harvest schedule. Trees which were uneconomic to recover were simply felled in the first harvest visit and left in the stand.

5.5.6 Constraints of MARVL Inventory and Software

There are several issues to be considered when implementing the MARVL system including:

- selecting the correct volume, taper and breakage functions;
- selecting the correct growth and height model;
- the experience of inventory personnel (experienced personnel are required to produce consistent and accurate inventory information);
- setting of log prices and grades (inappropriate log prices can affect log allocation in the log making process and impact on revenue);
- inappropriate log allocation (e.g. MARVL may allocate a small number of high value logs in the software but in reality, issues around haulage and markets would rule out allocation of these logs);
- selecting appropriate future harvest dates (most models are not designed for predicting growth and yield past 5 years);

These issues place limitations on results and predictions derived from MARVL analysis. Regular reconciliation and auditing with actual forest data is the best means to assess the validity of MARVL predictions and this will be carried out under normal forestry practice.

Chapter 6

Economic Evaluation

6.1 Introduction

This economic evaluation aims to fulfil six primary goals including:

- providing a liquidation value if the forest were to be felled today;
- providing a NPV of normal forestry practice (clearfell harvesting) for evaluation with other investment opportunities;
- providing a NPV resulting from forestry practice more suited to a forest park environment (coupe harvesting and CCM);
- testing NPVs for sensitivity to important variables like discount rate, costs and revenues, and growth models;
- providing cashflow scenarios for each different harvesting regime;
- providing a suitable silvicultural regime for future establishment of radiata pine.

The area of Cashmere Forest over which the economic evaluation is pertinent is generally described as that are currently under production forest and this is the case for normal cashflows. However, the discounted cashflow (DCF) analysis only pertains to those areas of radiata pine planted between 1979 and 1997 and those areas of Douglas fir planted in 1980 comprising a total of 292.73 ha. The economic evaluation by normal cashflow includes areas of radiata pine planted in 2000 and 2002 and an area of Douglas fir planted in 1994 comprising a total area of 340.26 ha. All economic evaluation is performed on pre-tax cashflows, no calculation of tax or estimates of tax are made in these analyses.

6.2 Liquidation Value

A liquidation value for Cashmere Forest is the value of the forest if it was clearfell and sold today. The liquidation value only applies to those areas of radiata pine planted from 1979 to

1997 and Douglas fir planted in 1980. The value of radiata pine planted in 2000 and 2002 and Douglas fir planted in 1994 is calculated as zero therefore the land area that the liquidation value applies to is 292.73 ha. The liquidation value for Cashmere Forest is \$1 271 350 or around \$4 343 per ha. This value is estimated with the use of costs, revenues and yields outlined in Chapter 5.

6.3 DCF – Clearfell Harvesting

6.3.1 Harvest age

Initial DCF analysis on the clearfell harvest option for Cashmere Forest concentrated on identifying an optimal harvest age for economic return. Ages of 25, 30, 35, 40 and 45 years were selected for the modelling process. NPV was found to clearly maximise at age 30 at a value of \$1 402 031 (Figure 6.1) or around \$4 790 per ha.

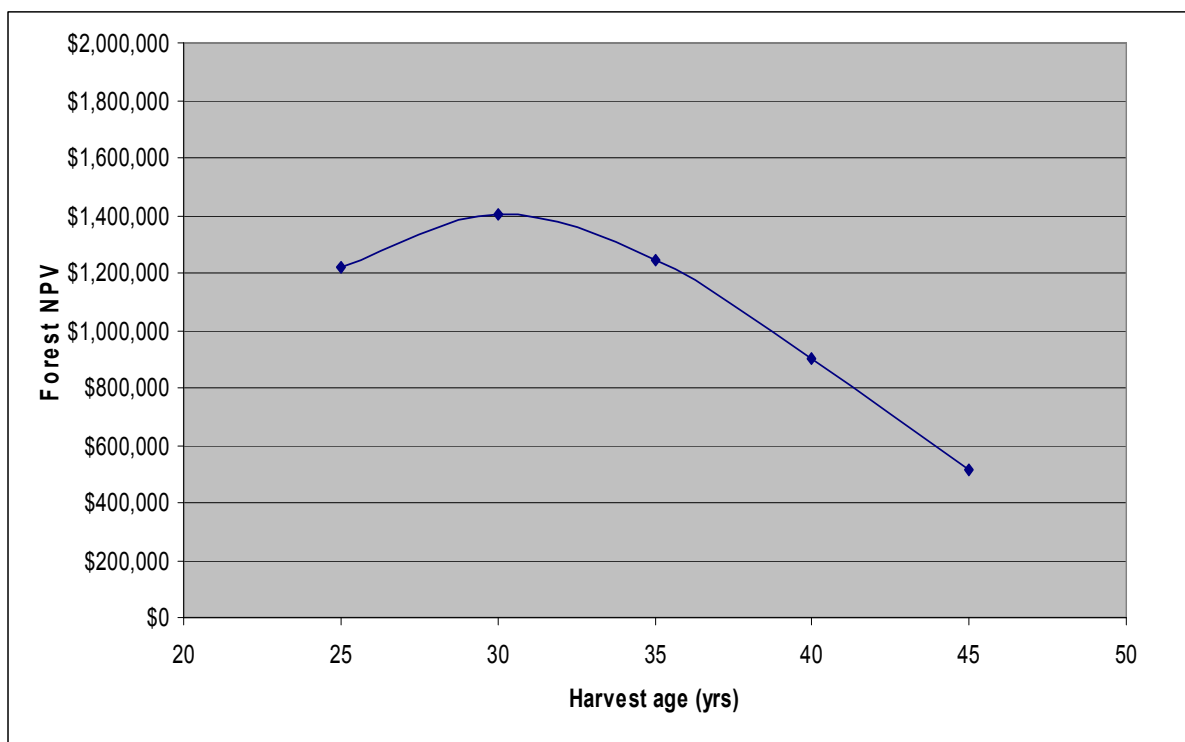


Figure 6.1: NPV's for alternative harvest ages under a clearfell harvest regime in Cashmere Forest.

6.3.2 Sensitivity Analysis

Discount Rate

Sensitivity analysis was carried out on changes to the discount rate to test the effect on NPV. This analysis highlights how the optimal harvest age can change following adjustments to interest rates. Alternate discount rates of 7% and 11% were used for this purpose. The optimum harvest age increases slightly to c.31 years at a discount rate of 7% where the cost of capital is less and the NPV increases by 28%. If the discount rate is increased to 11% the effect on rotation age is similar with the optimal harvest age appearing to drop by one year to around 29 years with a 20% decrease in NPV.

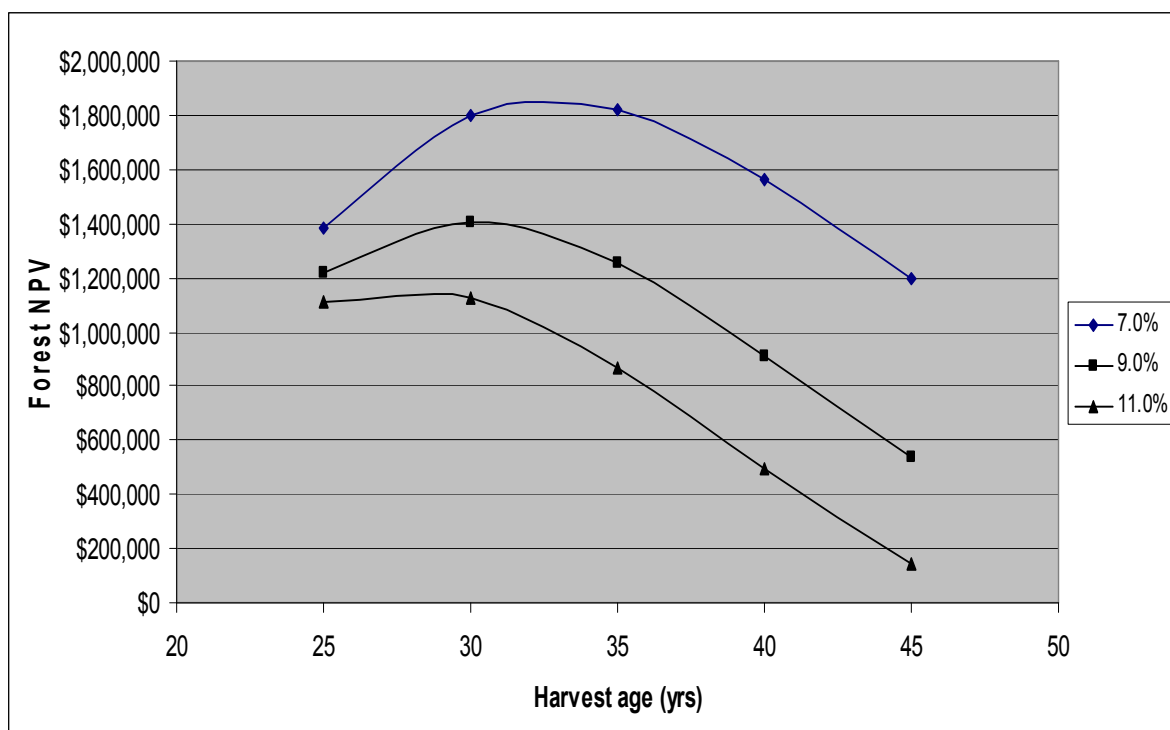


Figure 6.2: Sensitivity of a clearfell harvest NPV to changes in discount rate in Cashmere Forest.

Break-Even Discount Rate

The break-even discount rate is the rate at which liquidation becomes a more attractive option than continuing operations. If the harvest age is held at 30 years the discount rate would have to reach c.9.9% (NPV \$1 267 582) before liquidation became an attractive option.

Harvesting and Haulage Costs

Sensitivity analysis on harvesting and haulage costs aimed to identify the effect on NPV of likely rises (or falls) in fuel or labour costs. These costs were decreased by 5% and increased by 5, 10 and 20% across the board. Figure 6.3 demonstrates that if costs were to increase by 20%, NPV would decrease to \$764 838 which represent a reduction of around 46%.

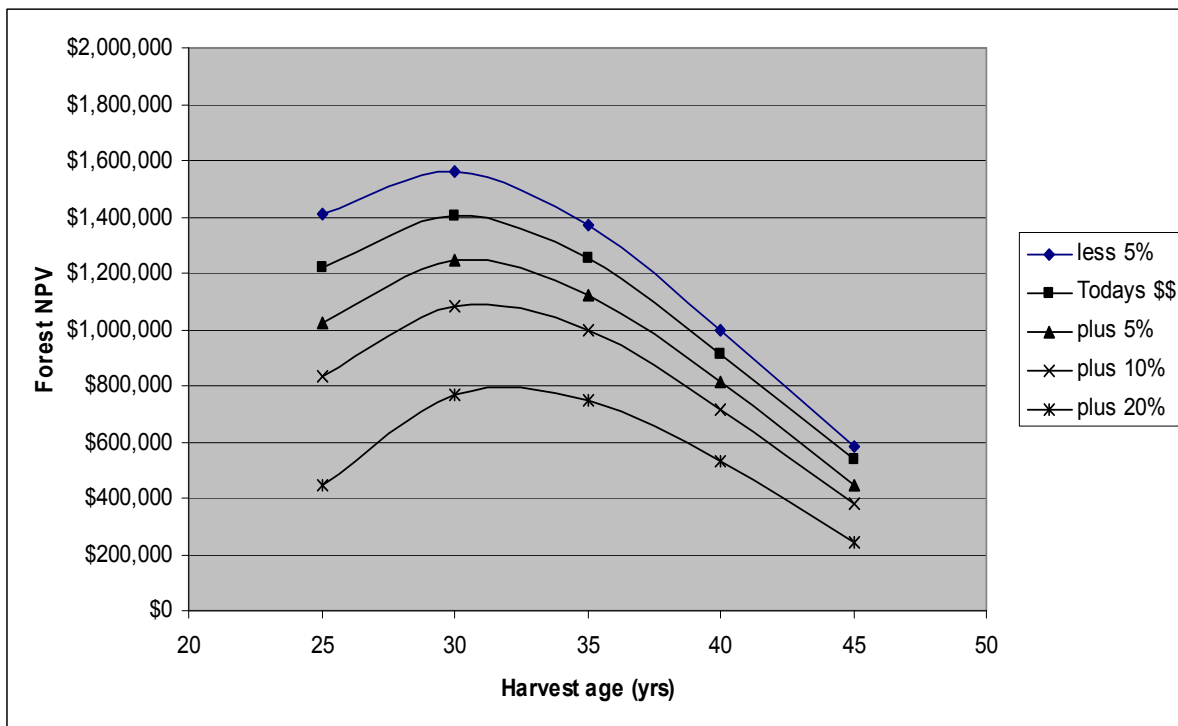


Figure 6.3: Sensitivity of clearfell harvest NPV to changes in harvesting and haulage costs in Cashmere Forest.

6.3.3 LEV

A figure for LEV for Cashmere Forest was determined by excluding land rental from NPV calculations. LEV reflects the maximum that can be paid for land to receive a given discount rate. The figure for LEV on a thirty year rotation is \$1 579 946 or \$5 397 per ha, a c.13% increase on NPV following removal of land rental from calculations. There are certain assumptions that are attached to LEV and NPV calculations that are covered in the constraints section of this chapter.

6.4 DCF - Coupe Harvesting

6.4.1 Harvest Dates

Initially coupe harvesting was modelled by harvesting each stratum at 25, 30, 35, 40 and 45 years; harvest dates were then aggregated across forest stratum to reduce forest visits. Initial coupe harvesting evaluation resulted in an NPV of \$727 776 which reduced to \$571 864 (or \$1 954 per ha) when harvest dates were aggregated representing a reduction of c.21%. The reduction in NPV is caused by factors including:

- no adjustments were made to operational costs to reflect the aggregation of forest visits (operational costs should reduce with aggregation as relocation costs are minimised);
- the method in which aggregated harvest dates were assigned has resulted in significant movement away from the optimum rotation age of 29 to 30.

All further DCF analysis of the coupe harvesting regime is undertaken using aggregated harvest dates.

6.4.2 Sensitivity Analysis

Discount Rate

As with DCF under the clearfell harvesting regime, the effect of discount rate on NPV was evaluated for rates of 7% and 11% (Figure 6.4). Movements in NPV were relatively larger than under a clearfell harvest regime with a 60% (7%) increase and 40% (11%) decrease. This is probably due to the extended timeframe over which operations take place in a coupe harvest regime.

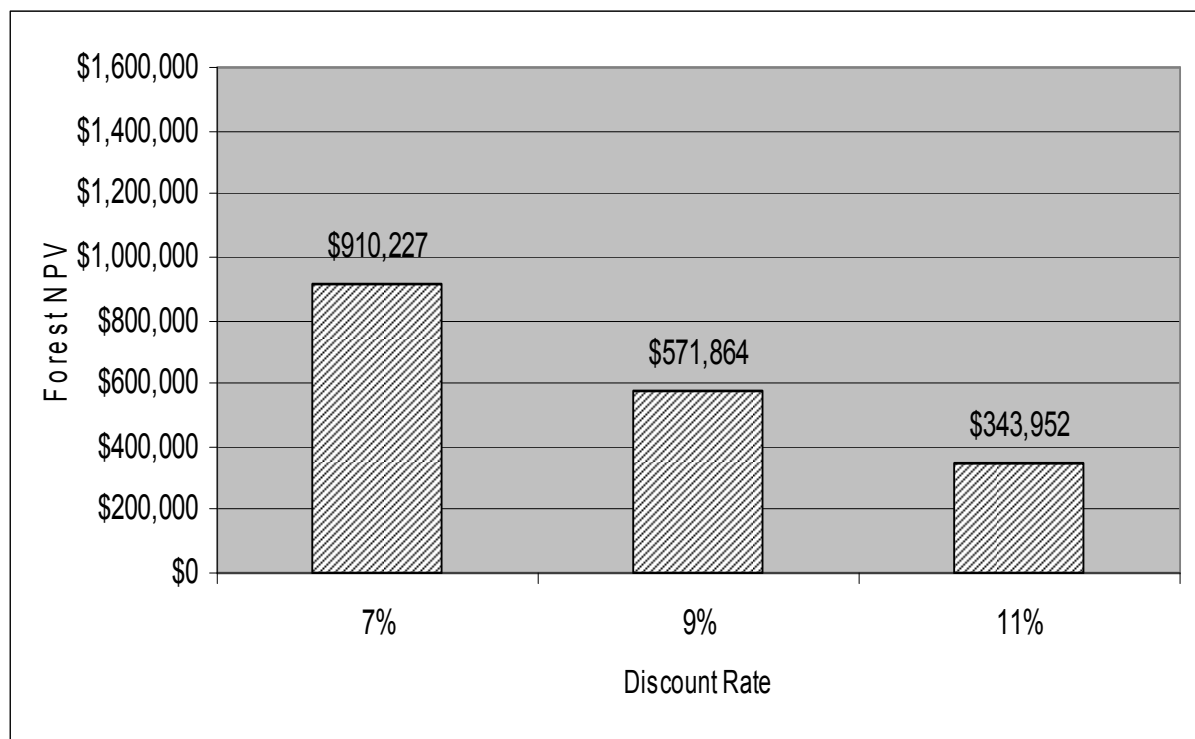


Figure 6.4: Sensitivity of coupe harvest NPV to changes in discount rate in Cashmere Forest.

Harvesting and Haulage Costs

Sensitivity analysis carried out on harvesting and haulage costs under a clearfell harvest were mirrored under a coupe harvest regime. It should be noted that if a conservative cost saving of 5% resulted from aggregation of coupe harvest dates then the reduction in NPV resulting from aggregation (21%) would be largely recouped (Figure 6.5).

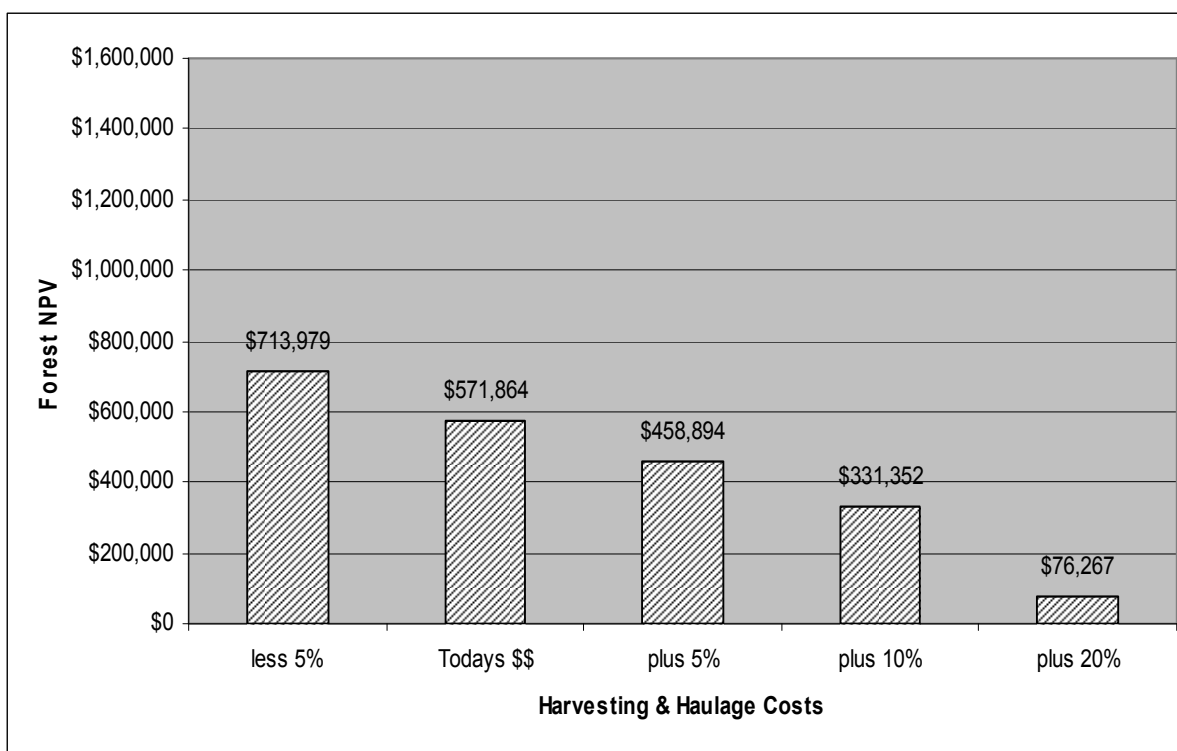


Figure 6.5: Sensitivity of coupe harvest NPV to changes in harvest and haulage costs in Cashmere Forest.

Log Prices

Sensitivity analysis was performed on log price estimates to reflect the effect of changes in the exchange rate and demand and supply for logs. Prices were changed relative to their current value i.e. higher prices are changed by a greater rate than lower prices (Table 6.1). This is consistent with historic log price trends¹⁹.

Table 6.1: Comparative changes to log price estimates for Cashmere Forest.

Grade	Log price (NZD per m³)		
	Increased	Normal	Decreased
P1	160	140	120
P2	130	115	100
S1	98	90	82
S2	87	82	77
S3	72	69	65
A	98	86	74
J	72	65	58
KI	57	55	53
Chip	42.5	41	40.1

¹⁹ <http://www.maf.govt.nz/forestry/statistics/logprices/index.html>. 05/03/2006.

Although price increases and decreases amount to the same value for each log grade the movement in NPV is dissimilar. Price increases resulted in an increase in NPV of 62% while price decreases lowered NPV by 45%. Therefore NPV seems more sensitive to price increases than decreases, possibly due to static costs of harvesting and haulage.

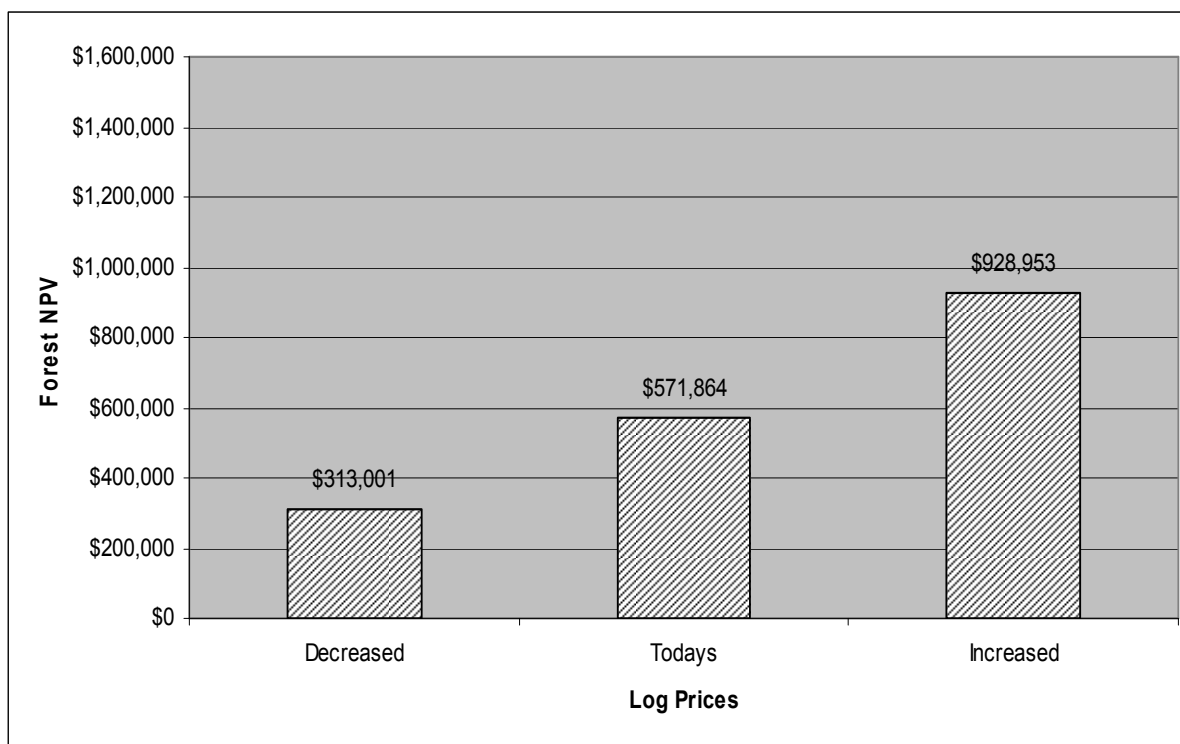


Figure 6.6: Sensitivity of coupe harvest NPV to changes in log price estimates for Cashmere Forest.

Model

Sensitivity analysis was carried out on MARVL yield predictions (Cant) by implementing alternative yield and growth models (Zhao) on the production component of Cashmere Forest. Models developed by Zhao (1999) predict stand basal area, MTH and volume. The implementation of these models resulted in reducing NPV from \$571 864 to \$352 344; a c.38.4% reduction in value. The reduction in predicted volume following implementation of Zhao's models evident in Figure 1 is typical across all strata in Cashmere Forest except stratum 10 (Table 6.2).

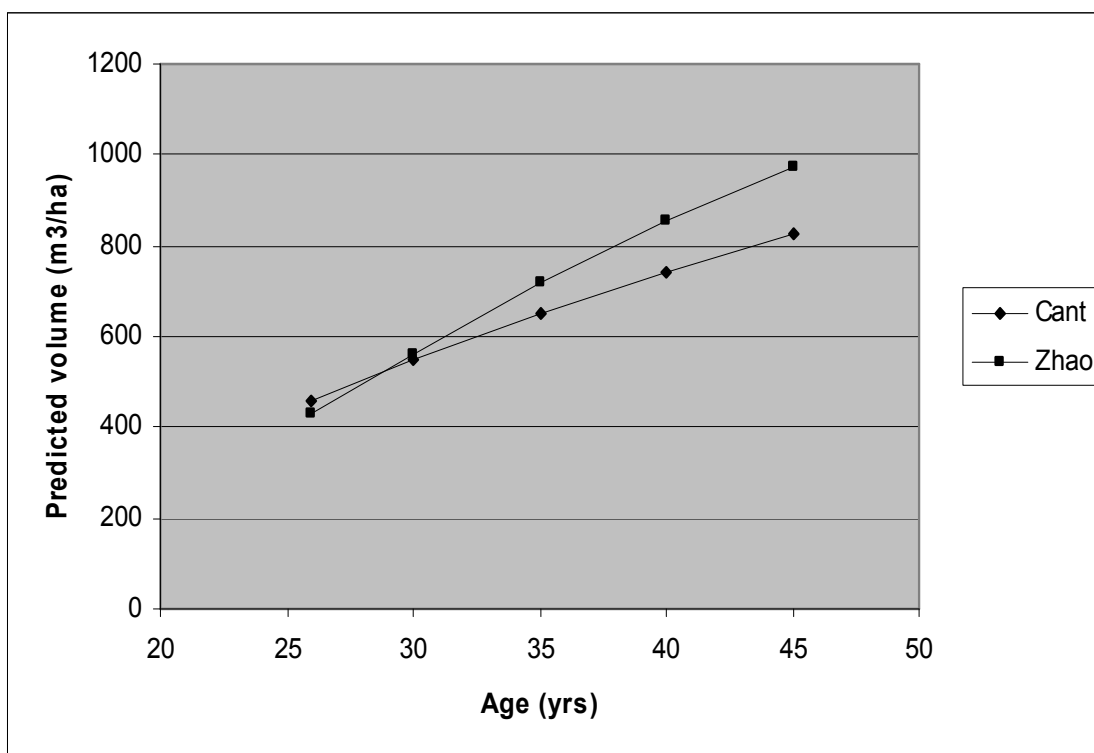


Figure 6.7: Volume predictions from different stand volume models for Stratum1, Cashmere Forest.

Table 6.2: Forest average percentage change in volume prediction following use of Zhao's models.

Age	% reduction in predicted volume (m3/ha)
25	1.1
30	8.4
35	11.9
40	14.3
45	15.6

6.4.3 Including CCM

NPV

CCM was implemented over six harvest visits realising an extended rotation of around 49 years for both strata. Analysis resulted in a 12% increase in NPV in stratum 3 and a 26% decrease in stratum 6. These differences evened out overall as stratum size had an effect resulting in a 1.7% decrease in forest NPV (Table 6.3).

Table 6.3: Values and percentage change following implementation of alternative harvest regimes in Cashmere Forest.

Harvest Scenario	Total Value	% Change
Liquidation	\$1,271,350	
Clearfell	\$1,402,031	10.28%
Adjusted Coupe	\$571,864	-59.21%
Adjusted Coupe / CCM	\$561,966	-1.73%
NSA (ha)	292.73	

LEV

A figure for LEV was calculated for this scenario as it reflects the most likely management option for Cashmere Forest. The LEV for coupe harvesting and CCM is \$739 881 or \$2 528 per ha. Removing land rental from analysis has improved LEV by a considerable 32% this is probably due to the long rotations under this management regime.

6.5 Normal Cashflow – Clearfell Harvesting

6.5.1 Background

Normal cashflows give an estimate of likely cashflow over the next 30 years. Costs and revenues are imposed to represent operational activity and harvest revenue. Some sensitivity analyses are performed to identify the effect of different growth models and silvicultural regimes on likely cashflow. As with DCF all normal cashflow analysis is pre-tax. Costs and revenues in all cashflow analyses except one are solely for the purpose of plantation forest management.

A final cashflow incorporating coupe harvesting and CCM has an annual restoration cost of \$40 000.00 added. While this provides a simple means of evaluating the economic impact of indigenous restoration it does not recognise factors which may force aggregation of restoration activity resulting in a disjointed cost burden.

6.5.2 Clearfell Harvesting

A normal cashflow was completed on a clearfell regime with a rotation age of thirty years to provide a point of reference for analysis of coupe harvesting and CCM. Figure 6.8 shows revenues and costs associated with clearfell harvesting over the next thirty years. Further graphs of cashflow will only include net revenue and accrued revenue to provide simpler viewing. The graphical series Accrued Revenue represents summed net revenue. This becomes positive around 2009 when large areas of forest become available (attain rotation age) for harvest. In the intermediary three years the forest will require funding from other sources. Costs are entered into cashflows as negative amounts, hence their tracking below zero.

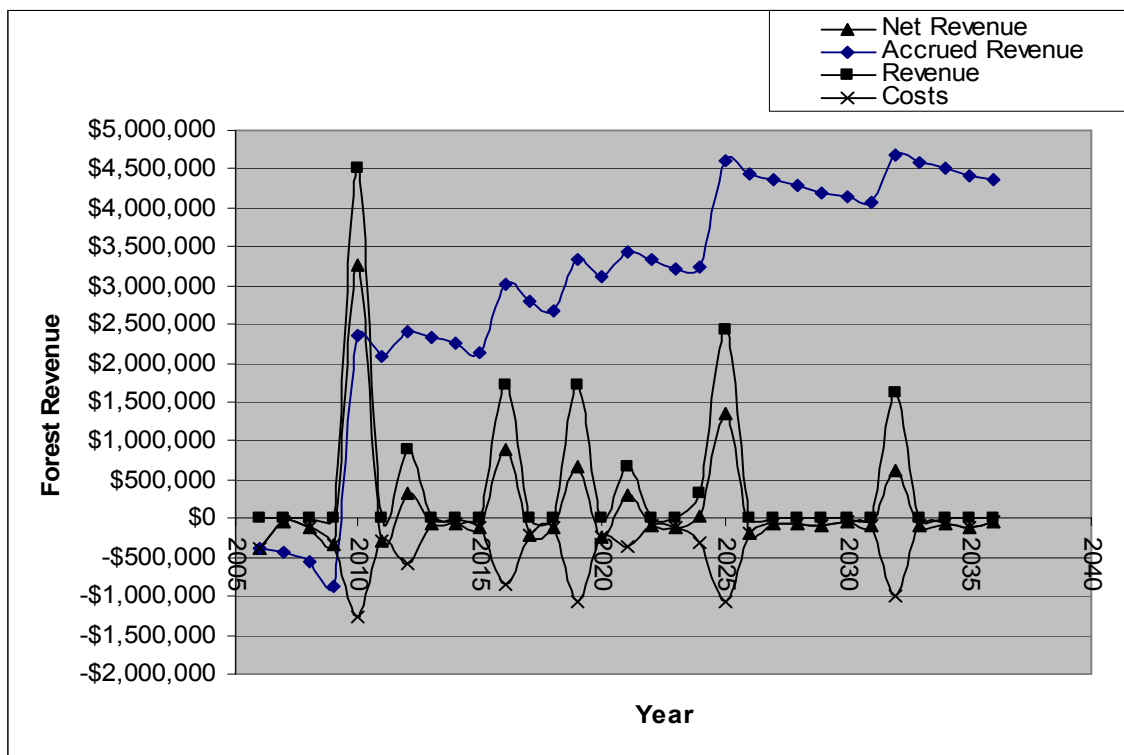


Figure 6.8: Likely cashflow arising from a clearfell harvesting regime in Cashmere Forest.

6.6 Normal Cashflow – Coupe Harvesting

6.6.1 Coupe Harvesting

Figure 6.9 shows the significant impact on revenue of coupe harvesting with Accrued Revenue becoming positive around 2017 but not becoming permanently positive until two years later at c.2019. As the costs and revenues of a coupe harvesting regime are smaller than under a clearfell scenario cashflow is less dramatic, prolonging the duration of negative cashflow. The 2036 value of Accrued Revenue is also significantly less dropping from around \$4.4 million under the clearfell scenario to \$3.1 million.

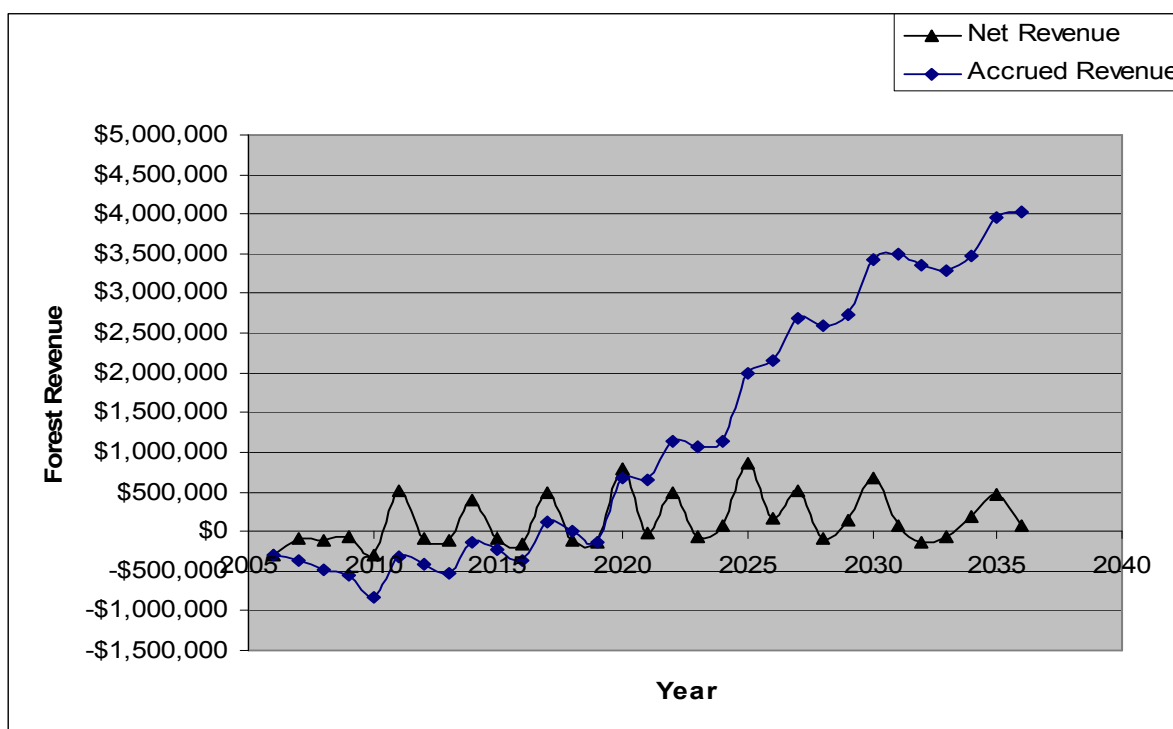


Figure 6.9: Likely cashflow arising from a coupe harvesting regime in Cashmere Forest.

6.6.2 Sensitivity Analysis

Sensitivity analyses on coupe harvesting cashflows involved implementing alternative growth models (Zhao 1999) for stand volume prediction and an alternative silvicultural regime (Figure

6.10). Reductions in predicted volume resulting from Zhao's models are seen to accumulate over the cashflow period, reflected in a significant drop in revenue at 2036 (Figure 6.10). An alternative silvicultural regime for the radiata pine component of Cashmere Forest involved re-establishment at 1200 stems per ha with three pruning visits (pruning up to 6 metres) and two thinning visits. The thirty year cashflow period only realises higher costs associated with more intensive silviculture and does not include the likely increase in harvest revenue associated with the silviculture. As with the previous analyses, positive cashflow does not become constant until around 2019.

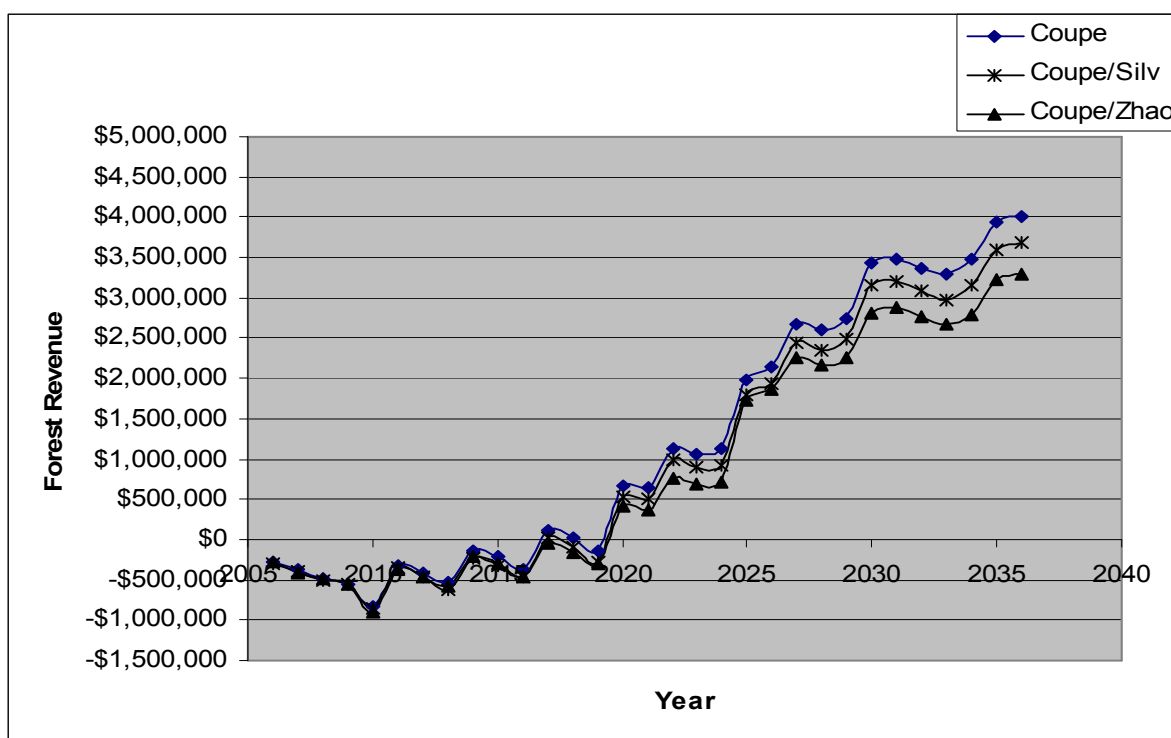


Figure 6.10: Likely coupe harvesting cashflows following implementation of alternative growth models and silviculture regimes in Cashmere Forest.

6.6.3 Including CCM

The trends seen in Figure 6.11 are a reflection of earlier trends where reductions in volume/revenue or increases in costs result in reduced cashflow over the period to 2036. The cumulative effect of lower revenue arising from CCM and then when alternative growth models and silviculture is applied is seen clearly. The extra annual cost (\$40 000) of indigenous

restoration also has a significant impact on cashflow. Indigenous restoration should not strictly be included in cashflow analysis as it is not a cost of normal forestry operations and it applies to the whole area of Cashmere Forest not just the plantation area. In spite of this it has been included to provide insight as to how indigenous restoration will impact forest cashflows. It is a positive outcome that long term positive cashflow is possible with indigenous restoration.

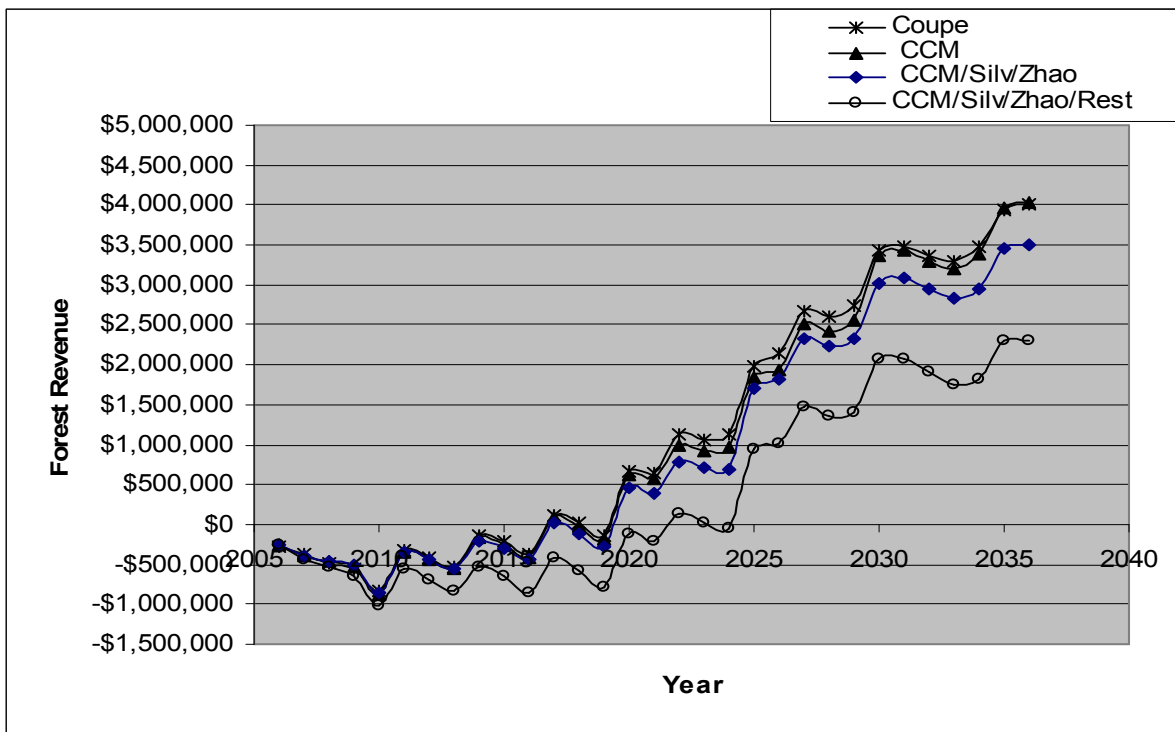


Figure 6.11: Likely cashflows following implementation of CCM in strata 3 and 6 and subsequent implementation of alternative growth models, silvicultural regimes and restoration in Cashmere Forest.

6.7 Discussion

6.7.1 Liquidation Value

The liquidation value is the value that the merchantable component of Cashmere Forest would recoup if it were to be harvested today. The value of \$4 343 per ha represents a 10% decrease in value from an NPV at the optimum rotation age. This implies that we are financially better off to continue practicing forestry under the current conditions than to liquidate the forest. The liquidation value does take into account future investment opportunities created through forest liquidation.

6.7.2 DCF

DCF provides us with a value today of forestry carried out in perpetuity on a certain land area. In doing this, DCF analysis balances the extra revenue generated from older trees with the increasing cost of capital investment inherent in longer rotations. This is evident in Figure 6.1 where NPV peaks at thirty years. This is also evident in the considerable reduction in NPV following implementation of coupe harvesting. Coupe harvesting extends rotation lengths to 45 years over which period, costs are constantly generated. The reduction in NPV resulting from harvesting outside the economically optimum rotation age represents the primary reason for the widespread use of clearfell harvesting in New Zealand's production forests.

It is doubtful if clearfell harvesting would be implemented in the forest park environment that is currently mooted for Cashmere Forest. However, analysing this scenario provides a value that represents normal practice forestry for comparison with other investment opportunities and a point of comparison for other management regimes. The NPV of \$4 790 per ha is reasonable in a forest this size considering the required level of investment on infrastructure and the price premiums on operations inherent in smaller forestry blocks. Sensitivity analyses around the discount rate and harvesting and haulage costs did not identify any abnormal effects arising from changes to these factors.

LEV is calculated for a clearfell scenario for the same reasons stated above. A land value for purchase of Cashmere Forest should reflect the most economically attractive management regime and this is realised in a clearfell regime. This is the value that a vendor would be most interested in attaching to the forest.

Although the implementation of coupe harvesting in Cashmere Forest results in a major reduction in forest NPV, it does remain well above zero which infers operational viability. A 60% loss in value results largely from harvesting at rotation ages other than the optimum (30 years) and the extra cost of increasing operational visits. However, intrinsic values that are not so easily measured become more important in a forest park environment such as Cashmere Forest and these values usually increase upon implementation of less drastic harvesting activity. It is because of these values and the retention of positive NPV that coupe harvesting is viewed as a feasible management option.

The loss in value arising from aggregation of coupe harvest dates is also significant but again falls under the umbrella of improving other forest values. Reducing operational visits will reduce the impact on recreational users, forest biodiversity and infrastructure while also saving money. For this reason, the aggregation process is an incomplete analysis as no financial reward is attributed for the reduction in operational visits. All operational activity including harvesting and silviculture will benefit/reduce following aggregation of dates as will maintenance on infrastructure like haul roads and landings. Therefore if we consider a conservative financial reward of a 5% reduction in harvest costs, our loss in value due to aggregation is considerably less (1.9%).

Sensitivity analysis on coupe harvesting NPV also identified no abnormal effects from changes to discount rate, log price and harvest and haulage costs. It is interesting to note that improvements in financial conditions like a lower discount rate or better prices has a greater effect on NPV than more detrimental financial conditions. Implementing alternative growth models is perhaps the most important sensitivity analysis carried out in this project. Revenue following implementation of these models is the least of all analyses and provides a minimum NPV for Cashmere Forest. It is foreseeable that these models may result in improved yield prediction over the Cant models and require full implementation; however this will not be assessable until some forest harvesting takes place and actual yields can be used for reconciliation of stand statistics.

Implementation of CCM which resulted in a minimal reduction in NPV is encouraging support for this forest management regime. However it was expected that both stratum would perform better economically under CCM than under coupe harvesting. The reduction in NPV for stratum 6 may be due to the process of selecting one plot (which had poor sawlog recovery) to represent the whole stratum. The manner in which harvesting costs are accrued under actual management may also improve financial returns for CCM (see Chapter 5). In light of these issues CCM is seen as a valid option for trialling in areas appropriate for ground based machinery in stratum 6 (100%) and stratum 3 (c.68%).

6.7.3 Normal Cashflow

Normal cashflows are useful for displaying fluctuations in revenue and cost over the cashflow period. Most notable in Figure 6.8 is an early negative cashflow and the mirroring of cost and revenue spikes representing harvesting and haulage costs and harvest revenue. Under normal forestry practice in large commercial forests, yields are regulated to induce positive cashflow, even out fluctuations in harvest revenues and to ensure continuity of supply. These regulation practices usually impact negatively on forest NPV and are not viable in this small scale analysis where other forest values are more important than a regulated cashflow. The fluctuations seen in accrued revenue resulting from those cost and revenue spikes are relatively significant but are able to be planned for and accommodated especially following permanent positive cashflow.

The early negative cashflow displayed across all normal cashflows is due to the accrument of cost with no reciprocal gathering of revenue; this is caused by two primary factors. Firstly, the accrument of costs prior to any forest area harvested, namely:

- the construction of the main access track in the first year;
- the construction of haul roads in the year prior to operational use;
- the onset of annual administrative costs beginning from purchase date.

Secondly, the temporal delay between beginning of management and harvesting, namely:

- under clearfell harvesting where no forest strata reach optimum rotation age (30 years) until 2010;
- under coupe harvesting where the immediate harvesting of younger trees (25 years) does not recoup sufficient revenue initially to offset costs.

The addition of sensitivity analyses into normal cashflows is reflected in progressively widening gaps between accrued revenue for different scenarios. This reaches an extreme case where the onset of indigenous restoration delays positive cashflow till around 2024. Positive outcome from this analysis is the general mirroring of levels of accrued revenue for each scenario suggesting no exceptional effects arising from sensitivity checks.

The two most important outcomes from normal cashflow analysis concerning the management of Cashmere Forest are seen as:

1. The delay until positive cashflow becomes permanent under a coupe/CCM regime.
2. The positive accrued revenue following thirty years of management.

While the first outcome is a point of concern as financial support will be required up to 2019 the attainment of permanent positive cashflow following this should make gaining that financial support easier.

It should be noted once again that all DCF and normal cashflows are pre-tax and do not incur interest for negative or positive cashflow.

6.8 Conclusions

Conclusions derived from the economic evaluation of Cashmere Forest are as follows:

1. There is a positive liquidation value for Cashmere Forest which infers the forest has value and if it were liquidated today, important infrastructure would be completed through operational necessity, remaining for future land management.
2. Cashmere Forest is capable of a good NPV for normal forestry practice in Cashmere Forest; providing good comparison for other investment opportunities and giving economic scope for alternative, more expensive management options.
3. Cashmere Forest is capable of a reduced but positive NPV resulting from coupe harvesting and CCM; providing validity to the implementation of these management techniques which realise other forest values.
4. Sensitivity analyses did not identify significant undue effects from changes to discount rate, costs or revenues. Even though changes to growth models result in considerable reductions in NPV and normal cashflow, they remain positive which provides confidence.
5. Normal cashflow analyses of a range of scenarios all return positive accrued revenue at the end of the cashflow period (30 years). Alternative support will be required until c.2019 if coupe harvesting and CCM is implemented in Cashmere Forest. However, following this the forest should be self supporting.

6. The silvicultural option of high pruning tested during sensitivity analysis is recommended for implementation as it will provide improved revenue when harvesting takes place. Analysis can not be realised in discounted cashflows which uses projections of the expected returns from the current crop. It is not possible to forecast returns for a high pruning option.

6.9 Constraints on Economic Evaluation

Listed below are some constraints and assumptions involved with the economic evaluation of the plantation area in Cashmere Forest.

Constraint: There was no historical growth data from Cashmere Forest available for analysis with the recent MARVL inventory. Comparisons between historical growth data and current inventory allow auditing of growth and yield predictions from growth models.

Response: As initial harvesting takes place actual tree volumes can be used to reconcile growth model predictions. These reconciliations can be used to adjust future predictions of growth and yield.

Constraint: There is limited cost information for forest management activities like harvesting and silviculture carried out under coupe harvesting and/or CCM regimes. This reduces the validity of any estimates of these costs used within this analysis.

Response: If the forest park concept for Cashmere Forest proceeds then implementation of these specialised management activities will provide real costs to be used in future economic analyses.

Constraint: Very limited cost information for forest management activities carried out on alternative species under coupe harvesting and/or CCM regimes. This makes it very difficult to provide estimates of these costs for economic analysis.

Response: If the forest park concept for Cashmere Forest proceeds then implementation of these specialised management activities will provide real costs to be used in future economic analyses.

Constraint: The NSA for all economic analysis is assumed to remain constant for the lifetime of the analysis; this will not be the case as the implementation of planned subdivisions and indigenous restoration proceeds. These activities will remove area from the current plantation area. Difficulties also arise in analysis where areas of subdivision and indigenous restoration occur across the forest park in a disjointed manner. The final arrangement and boundaries of these areas is still to be finalised which also complicates further analysis.

Response: The economic analysis using the current NSA provides a valuable insight into the current economic potential of Cashmere Forest. As areas for subdivision and indigenous restoration become finalised more analysis will become feasible. It should be noted that indigenous restoration will be an ongoing issue with edge boundaries between plantation and non plantation areas constantly requiring adjustment.

Constraint: No provision has been made within cashflow analysis for the cost of forest inventory or monitoring or the supervision of inventory and silvicultural operations.

Response: It is expected that the majority of these activities will be conducted by students and as such funding may be available from research grants and other sources. Therefore the level of cost that Cashmere Forest is required to meet should not be substantial and will apply as a constant across all management scenarios. Supervision of these activities should also be covered in the same manner.

Constraint: No provision has been made for inflation over the life time of the economic analyses.

Response: This is usual practice as any inflationary pressure is likely to affect both prices and costs at the same rate. Likely pressure on fuel prices has been explored through sensitivity analyses.

Assumptions:

- That best practice forestry is carried out on the land.
- Forestry is carried out on the land in perpetuity.
- Should be calculated “looking forward”.
- That forestry is the highest and best land use (if subdivision is also considered as a land use then the opportunity cost of the land is the land market value under subdivision) (Manley 2005).

Chapter 7

Constraints to Management of Cashmere Forest

7.1 Background

Constraints to management are those factors that are likely to significantly hinder the success of both the 5 and 30 year management outcomes for Cashmere Forest. Any impact on management outcomes also has potential to hinder the ability to achieve the long term vision for Cashmere Forest. Constraints are addressed within the production or ecological component of the forest covering environmental, forest management, biotic, regulatory, economic and social issues. Early identification of constraints allows the formulation of appropriate management responses to deal with these issues and mediate forest management success and the attainment of long term vision statements.

7.2 Environmental Constraints

Constraint: Wind is a very important consideration in forest establishment in the Canterbury region made evident by significant wind damage to planted forests in the area over the last 50 years. Wind can devalue production forests in several different ways including:

- significant windthrow of large areas of crop trees;
- isolated windthrow or toppling of single trees or small groups;
- windthrow or toppling of trees around edges of harvest sites;
- breaking the tops out of trees, halting growth and providing pathways for decay;
- creating resin pockets which downgrade sawn timber.

Wind can also impact on management and recreation values within a forest park environment. Flying debris (dead branches, pine cones etc) and windthrow across tracks creates health and safety issues for all forest users, while extensively windthrown forest impacts on aesthetic values.

Response: High initial stockings will be retained longer into the crop cycle meaning that trees provide mutual support in wind events. On slopes that are exposed to the northwest or southwest, rows should be planted in these directions to aid mutual support. Thinning operations will be relatively light; maintaining good canopy closure and tree support. Coupe harvesting will be managed in terms of size, shape, and location in the landscape to mitigate wind risk for residual trees. Species selection for re-establishment will reflect areas of high wind risk. Some species are more wind-firm and / or tolerant of wind than others. Public notice boards will relate all wind safety issues and windthrow response actions to the public. Obstruction by windthrow along main access tracks will be cleared as soon as possible. The incidence of resin pockets and their importance will be assessed following processing of local sawlogs.

Constraint: The low annual rainfall and high incidence of summer droughts will restrict production and native species selection in Cashmere Forest. Low soil moisture during summer will also restrict the timing and success of establishment and restoration operations as will utilisation of the soil moisture by exotic grasses and weeds. Frost may be a problem in Valley bottoms.

Response: Experience from other native restoration plantings in the Port Hills suggest that winter establishment is the best time for successful establishment. Production species will be selected for their ability to cope with local rainfall conditions while native plantings will be of species typical of and naturally adapted to the Port Hills region. Site selection for different species will reflect the altitudinal rainfall gradient and the topographical soil moisture gradient. Initial weed control before planting and subsequent release spraying/manual clearing after planting will be required for production species establishment and native restoration plantings.

Constraint: The shallow soil depth on ridge shoulders and around rock outcrops will restrict species establishment and track construction in these areas. The high risk of erosion in the Port Hills soils will also effect track construction, maintenance, landing construction and forest harvesting practices.

Response: Tree establishment on shallow soils will be aided by good planting practices which reflect these conditions, or alternatively, these areas will not be replanted in production species. Track construction will be planned to avoid areas of shallow soil and exposed rock. Track and landing construction will be planned to minimise the area affected and negative impacts of these structures. Track construction and maintenance and forest harvesting practices will all be in accordance with the New Zealand Environmental Code of Practice for Plantation Forestry (NZFOA 2006). Where possible, forest harvesting operations will be adapted to retain forest residue on site reducing soil erosion and stream sedimentation risk.

Constraint: Establishment of the existing production forest through stream beds means that some harvesting will be required in these areas. Forest harvesting along streams results in elevated organic matter in stream beds which restricts flow and alters nutrient levels. Harvesting along streams also increases the risk of sediment reaching the stream bed. This is already evident in the siltation of several dams in Cashmere Forest.

Response: Forest harvesting practices will be adapted to minimise the levels of slash reaching stream beds. Standard harvesting procedures and guidelines will be adhered to to minimise the creation of sediment and the amount of sediment reaching streams (SPBL 2005). The implementation of riparian buffers as harvest areas are re-established will negate these risks in the future.

Constraint: The risk of fire is elevated in Canterbury due to the hot dry climate, the occasional strong dry winds that occur in summer and the large urban population. Limited control on access to forest users can create opportunities for accidental or deliberate fire ignition. Fire has the potential to destroy significant areas of Cashmere Forest once established. Recent fires in similar recreational forest park areas in Christchurch highlight this risk.

Response: Fire risk planning and response is addressed fully in a Recreation Management Plan for Cashmere Forest. All forest users will be made aware of the fire risk to Cashmere Forest through appropriate signage and information. No open fires will be allowed within Cashmere Forest during summer. Fire access and escape routes will be well signposted around the forest. Dams within the forest need remedial repair to allow them to serve as small reservoirs for ground based fire crews. Several concrete water tanks are scattered around the property which could also

act as small reservoirs. Public vehicular access to the forest will not be permitted at night time. Consultation will be carried out with adjacent landowners to assess local preparedness and likely response to fire risk.

7.3 Forest Management Constraints

Constraint: The current track network within Cashmere Forest is limited and not suitable for heavy traffic like logging trucks. The lack of tracking also restricts vehicular access and consequently harvest machinery, vehicles providing restoration services and fire management to large areas of the forest. Access requirements for forest harvesting will increase in the future as riparian areas and small group management require more intensive management.

Response: There is a preliminary plan for the construction of an extensive track network which will facilitate and accommodate forest harvesting, native restoration and provide permanent access and escape routes for fire control. This preliminary plan will require updating within a formal harvest plan accurately demarcating ground based and cable logging areas and formalising the location of haul roads and landings. Haul roads and tracks will be permanent and will also facilitate the expansion of the recreation track network.

Constraint: The construction of tracks on steep erosion prone country can result in significant sediment production. This is evident in the silting up of dams following salvage operations c.2000.

Response: All track construction will be within specific environmental guidelines and regional guidelines (Appendix 4; NZFOA 2006) which aim to minimise environmental consequences arising from these actions.

Constraint: A considerable component of Cashmere Forest terrain is quite steep. Slope sampling during forest inventory found the average steep slopes to be around 25°. Most ground based harvest machinery operates on a maximum slope of around 18°; therefore large areas of

Cashmere Forest will be too steep for ground based operations. The steep terrain will also make track and landing construction slow and difficult.

Response: A preliminary harvest plan for Cashmere Forest incorporates a cable harvesting system for use on steep terrain. This system is more expensive than ground based machinery but cheaper than aerial extraction with helicopters and requires less tracking and ground surface disturbance. The amount of tracks and landings constructed and their placement will be carefully planned to minimise construction cost and effort.

Constraint: Two sets of high voltage power lines and pylons cross Cashmere Forest running generally parallel in an east west direction. Harvest operations and further production forest establishment will be restricted in areas directly under these lines where they are low enough to the ground that a mature tree may impact on them.

Response: In all areas of production forest, which lie under these pylons in close enough proximity to impact the lines, the trees have been felled. These areas of land have been mapped using aerial photography and designated as areas for future native restoration in short stature broadleaved species.

7.4 Biotic Constraints

Constraint: Invasive weeds like gorse, broom and blackberry may hinder the successful re-establishment of production species and restoration plantings in Cashmere Forest. Weeds species compete directly with production and native species for moisture, nutrients and space resulting in poor establishment and initial growth of these species. These weeds are present in the environment and will germinate in response to soil disturbance and increased light levels following harvesting. Ongoing seed spread of exotic species from adjacent areas is also likely to be a problem.

Response: Best results for establishment after harvesting are achieved when weed species are allowed to germinate and occupy a harvest site. A desiccant spray is then used to kill all

germinating plants, after which the planting of production or native species is carried out. Following establishment of these species, release spraying/manual clearing is conducted to account for the re-emergence of persistent weed species. Initial stockings of production species are kept high to minimise the time elapsed until site occupancy occurs. Forest harvesting practices will be adapted to minimise soil disturbance which aids weed germination. Future goals of continuous canopy management and native restoration for Cashmere Forest will further reduce the opportunities for weed establishment.

Native restoration in non plantation areas will also have initial weed clearance of some form, either herbicide spraying or manual clearing. This will be carried out at each establishment site with weed mats installed around each seedling to suppress further weed growth in the vicinity of the plants roots. Ongoing monitoring of established native restoration sites will determine the requirement for further weed control in these areas.

Constraint: Animal pests present in Cashmere Forest will impact on the survival and growth of production species, native restoration plantings and native fauna. Antler rub from red deer, browsed vegetation and sightings of hares, goats, mustelids and possum trails are visible evidence of pests that occur at present. These species have the potential to impact the establishment and growth of production species and native flora and fauna. Browsing of mahoe seedlings is currently evident throughout the production forest understorey.

Response: A pest management strategy will be developed upon purchase of the Cashmere Forest. The pest management strategy will initially aim to substantially reduce the numbers of all animal pests within the forest. This will occur as soon as practical by hunting, poisoning and/or upgrading of boundary fencing. Eradication of animal pests is unlikely due to reinvasion, therefore ongoing pest control will be required to maintain these animals at low levels. Providing the owners of neighbouring properties with the Cashmere Forest pest management strategy may promote wider appreciation of pest issues.

Constraint: Domestic stock (cattle, goats and sheep) currently have access to the Cashmere Forest. Stock can limit the viability and growth of naturally regenerating and artificially restored indigenous and production species through grazing and trampling. Cattle also traffic and degrade riparian areas within Cashmere Forest.

Response: A primary response is to discontinue the grazing rights of adjacent landowners which will restrict cattle from entering Cashmere Forest. Boundary fences will also need upgrading in areas where stock are present on adjacent properties to stop stock pushing through these fences. Boundary fences will need ongoing monitoring to ensure future integrity.

Constraint: Current and proposed residential development around and within Cashmere Forest will create greater opportunities for cats and dogs to impact on indigenous flora within the forest. Cats prey on birdlife, lizards and geckos while dogs would seriously hinder re-introduction of the flightless buff weka.

Response: The recreation management plan outlines the possibility of a predator proof fence around Cashmere Forest. Surrounding residential properties will also be made aware of the importance of restricting pet movements in the area and any residential development within Cashmere Forest could have caveats on pet ownership or requirements for the provision of adequate fencing of properties.

7.5 Regulatory Constraints

Constraint: Restrictions on land and vegetation management in the Port Hills is outlined in the Land and Vegetation Management Regional Plan, Part II: Earthworks and Vegetation Clearance Port Hills (1997). Forestry operations within Cashmere Forest will come under jurisdiction of this document. Forestry operations including harvesting, vegetation clearance, establishment, spraying, track and landing construction and maintenance and poison pest control are all addressed (Appendix 4; NZFOA 2006).

Response: All of the guidelines and restrictions outlined in the above document will be adhered to during all forest operations in Cashmere Forest. Following initial forest clearance from streams and track areas, the implementation of riparian areas and forest management practices specific to Cashmere Forest aim to satisfy the majority of regulatory restrictions.

7.6 Economic Constraints

Constraint: Track and landing construction, silvicultural work and native restoration plantings will require an injection of funding over the initial years of forest management. The delay of harvest dates due to coupe harvesting will mean low levels of revenue over this time period postponing the date that forest revenue will exceed expenses until c.2025. The low level of historic silvicultural investment in the current production forest will result in relatively lower returns from these trees.

Response: Residential subdivision and development of small areas of Cashmere Forest will allow the generation of substantial initial income. Depending on the level of income generated through the residential development, some money may need to be borrowed in the initial years of management to allow track construction and native restoration activities to proceed. Tracks and landings are only to be constructed as areas are required to be harvested, thereby spreading these costs over a longer time period. The low potential value of the current production forest is factored into cashflow exercises. Future production forest establishment will endeavour to capture greater value from trees through more intensive silvicultural investment. The amount of native restoration will be limited in initial years to reflect available funding.

7.7 Social Constraints

Constraint: The visual impact of forestry operations in a forest park in such close proximity to Christchurch city may cause concern with recreational forest users and the general public. The health and safety issues around day to day forestry operations might also concern recreational forest users.

Response: Forest management practices specific to Cashmere Forest aim to address the visual impacts of forest harvesting by restricting harvesting to small coupes of 2 to 5 ha. Eventually the visual impacts of harvesting will be largely mitigated under the long term forest vision of continuous canopy management and native restoration. This forest management information should be made available to the general public and forest users through appropriate signage. Any

production forest areas that are receiving treatment (harvesting, pruning, thinning etc) will be sign posted as off-limits to the public for the duration of the treatment for health and safety reasons. Consideration will be given to important recreation times or events when planning forest operations.

Constraint: Christchurch City as owners of a public recreation forest may come under considerable pressure from lobby groups with conflicting ideas for prioritising management and restoration goals within Cashmere Forest. Examples may include the species mix for restoration or pest control practices.

Response: Implementing public consultation processes as management of Cashmere Forest progresses will minimise opportunities for public dissatisfaction.

Chapter 8

Forest Park Management

8.1 Management Overview

8.1.1 Background

All forest management planning within Cashmere Forest must consider the long term (200 year) forest vision and its planning implications. The long term vision has a broader focus than traditional production forestry. Environmental, ecological and recreation values are assigned equal importance with production forestry and are integral components for the operational success of Cashmere Forest as a forest park. In order to accommodate all values, traditional forest management and practices must be modified to suit these management requirements. These modifications are now summarised as background to the management prescriptions to follow.

The importance of non-economic values to Cashmere Forest should not however curtail potential economic value creation within forest management as this will assist fund other activities. Of the current production forest older than 12 years only 19% has been high pruned. High pruning to a height of c.6m generates the potential for production of significant clearwood which has inherently greater value than unpruned timber. Increasing the level of silvicultural investment, especially pruning activities in all radiata pine is seen as a priority for management of this production species. A forest with a more intensive silvicultural history and greater inherent value would also allow the application of more selective harvesting practices as it would be a higher value forest.

The relatively low pruned, low value nature of the majority of the current production forest, and the steep terrain, limits harvesting opportunities within Cashmere Forest. For harvesting to remain economic while also accommodating other forest values, the harvesting of 2 to 4 ha coupes will be implemented with forest entries having a return period of 2 to 5 years.

As coupes are replaced with a higher value radiata pine forest, management options including ground based single tree or small group selection and the subsequent establishment of alternative production species becomes feasible. The greater potential of radiata pine to exclude weed competition on medium sized harvest sites is the primary reason for re-establishing coupe areas with this species.

As small group selection becomes feasible the establishment of production species that are poorer initial competitors and more shade tolerant will commence. In steep areas where ground based small group harvesting is not possible, appropriate coupes may be re-established with eucalypt species or Douglas fir, both of which have the ability to dominate a coupe area in the face of weed competition. The establishment of these species along with coast Redwood and Mexican cypress will create a heterogeneous canopy, enhancing the visual landscape of Cashmere Forest. As CCM progresses and a range of species and ages become established there will be less need for traditional blanket operations like waste thinning and management will assess silviculture options on a tree by tree basis.

The management options outlined above are some initial solutions to forest management requirements that also attempt to satisfy the broader values found in a forest park environment. The departure from traditional “tried and true” forest management practices is essential for the realisation of the broader values relative to Cashmere Forest. For future forest management to succeed in satisfying the full value set, the reasons behind the alternative management solutions must be fully appreciated and incorporated into management decision making.

8.2 Species Choice

8.2.1 Introduction

The establishment of a range of production species in Cashmere Forest is important on several fronts including:

- increasing the biodiversity of production areas;
- diversifying market exposure;

- diversifying income;
- aiding risk management.

However, the range of species that can be established is severely limited by the low precipitation and strong winds characteristic of the Port Hills area. Micro-climates exist in south facing areas and valley bottoms where soil moisture and wind protection increases, offering suitable opportunities for a wider range of species than is available on drier more exposed north facing areas. The ability of radiata pine to survive and grow on more exposed sites facilitates selection of alternative production species for southfacing or valley bottom sites. The successful establishment of radiata pine, Douglas fir and *Cupressus* spp. and *Eucalyptus* spp. in and around Cashmere Forest provides initial species for re-establishment capable of producing high value timber.

8.2.2 Radiata pine

Radiata pine originates from three locations (Ano Nuevo, Monterey, Cambria) along the west coast of California and two islands (Cedros, Guadalupe) off the Baja Peninsula, Mexico. It occurs over a wide altitudinal range (sea level to 1200 m), in varying rainfall and on a range of soil types. In spite of this, its ecological niche is limited by other species like Douglas fir and coast redwood where rainfall increases, and muricata pine where soils are poorer (Burdon & Miller 1992).

Radiata pine was first introduced into New Zealand in 1859 and during the 1860s mainly for aesthetic purposes, with the first significant seed importations occurring in the late 1860s to 1880s. The current (2004) radiata pine estate in New Zealand occupies 1 626 000 ha¹ or 89.2% of the plantation forest estate. The dominance of radiata pine as a plantation species is attributed to its fast growth, ease of establishment and care in the nursery and transplanting and the versatility of its wood (Burdon & Miller 1992). These qualities have been augmented since c.1920s with significant research programs aimed at improving establishment, growth, form and density. Treatments like pruning, thinning, kiln drying and preservative application all serve to enhance these improvements and the versatility of radiata pine timber.

¹ MAF Facts & Figures (2005/2006), New Zealand Forest Owners Association.

The main limitations for the establishment of radiata pine in Cashmere Forest are likely to be frost, snow and drought. Good establishment practices including appropriate timing and grass/weed clearance will avoid frost and soil moisture problems. The risk of snow damage is more difficult to protect against; snow accumulation on the lee side of exposed hills means that east/northeast faces are susceptible to south/southwest induced snow storms. The relatively steep and dry climate of the majority of these easterly faces necessitates re-establishment of radiata pine on these sites. While annual rainfall of 700 to 1000 mm is not optimal for great radiata pine growth, it is sufficient for successful establishment and survival (Burdon & Miller 1992).

8.2.3 Douglas fir

Douglas fir is native to western North America where it occurs in a broad coastal band between the Pacific Ocean and mountain ranges running from British Columbia to California (Lat 55°N to Lat 35°N). Through this range it generally occurs from sea level to altitudes of 800m in British Columbia increasing to 1800m in California where there is more rain (920 to 3200 mm). Douglas fir is found in mild humid climates with well drained soils of sedimentary or glacial origin or of volcanic origin at higher elevations (Miller & Knowles 1994).

First introduced to New Zealand in 1859, it currently (2004) occupies 112 000 ha¹ or 6.2% of the plantation forest estate second only to radiata pine. The majority of Douglas fir is used for structural or framing timber due to its good strength, stability and because preservative treatment is not needed when not in ground contact (this advantage may be nullified with new building codes due to be introduced which specify the use of treated timber). Poor finishing qualities due to abrupt changes in density across growth rings and the high cost of pruning this species restrict appearance grade market opportunities.

Miller & Knowles (1994) describe how Douglas fir can grow moderately well on sites with less than 1000mm of rainfall if establishment is on shadier south facing areas. High initial stockings and good seedling health are recommended for sites where weeds are a problem (Miller & Knowles 1994). Low rainfall (700 to 1000mm), characteristic of the Port Hills will limit initial

¹ MAF Facts & Figures (2005/2006), New Zealand Forest Owners Association.

stocking to avoid competition for soil moisture¹ to south facing areas and/or adjacent to riparian buffers.

8.2.4 Eucalypts

Of the 100 eucalypt species that have been introduced to New Zealand, *E. fastigata* and *E. obliqua* have been highlighted as suitable timber species for the Port Hills area (FRI 1984)². Both of these species belong to the ash eucalypt group which come from Tasmania and Victoria, and to a lesser extent New South Wales. Each species within the group is quite specific in site and climate tolerances. *E. fastigata* occurs naturally on loamy soils within the latitudinal range 30° 30'S to 37°30'S at altitudes between 300 and 1400 m with mean rainfall varying from 750 to 2000 mm. At lower altitudes (c.300 m) moist gullies are favoured. *E. obliqua* occurs naturally on a wide range of soils within the latitudinal range 28°S to 43°30'S at altitudes from sea level to 750 m with mean annual rainfall varying from 500 to 2400 mm (Miller *et al.* 2000).

Both eucalypt species were introduced to New Zealand in the late 1800s with *E. fastigata* becoming the more popular of the two due to its suitability for both pulp and sawn timber production, and its better health and adaptability. There are currently 33 000 ha of eucalypts planted in New Zealand occupying around 1.8% of the total plantation estate.³ Both species are suitable for high value timber products like flooring, furniture, veneers and turnery (Haslett 1988). However, eucalypts do require specialist processing to combat growth stresses which are released following felling and milling, and careful drying to avoid drying degrade. Therefore, New Zealand sawmillers generally require eucalypts to be over 60 cm DBH before harvesting; trees of this size are older and subsequently have less growth stresses and because of their size will produce more timber. Harvest ages to achieve 60 cm DBH will be around 35 to 40 years.

¹ <http://www.tussocks.net.nz/forestry/species/Douglasfir.html>. 22/05/06.

² Derrick Parry, Rangiora Nursery Ltd. Ph call. 13/06/2006.

³ <http://www.maf.govt.nz/statistics/primaryindustries/forestry/forest-resources/national-exotic-forest-2005/02-overview.htm#Species>. 18/07/2006.

Eucalypts will be planted in coupe areas adjacent to riparian buffers on drier slopes and mid slope in south facing areas. This aims to avoid the most exposed and dry areas while also providing some shelter and moisture. Planting in coupe areas is possible due to fast establishment and early suppression of weed species as opposed to other slower establishing conifers.

8.2.5 Mexican cypress

Of the cypress species present in New Zealand, Mexican cypress (*Cupressus lusitanica*) is recommended for commercial planting in Cashmere Forest^{1 2}. Mexican cypress originates from central and southern Mexico and the highlands of Guatemala, reaching to Honduras where it occurs at altitudes ranging from 1200 to 3000 m in isolated pockets on moist slopes or near streams. This species was first introduced to New Zealand in the 1860s; forest service plantings commenced in 1970 with seed sourced from Guatemala and another provenance in Kenya. In 1986 Mexican cypress comprised 7% (766 ha) of the 3400 ha of Cypress plantations in New Zealand (Miller & Knowles 1992). As at April 2005 the total New Zealand cypress estate had increased to 6 000 ha³ occupying 0.33% of the total plantation estate. The level of increase of Mexican cypress from 1986 to 2005 is unreported.

Fertile, sheltered sites with good rainfall (> 1000 mm) are described as a requirement for the good growth of this species by Miller & Knowles (1992). Within Cashmere Forest this limits site selection to areas adjacent to riparian zones, and sheltered south facing valley bottoms and sides. Cypress sawn timber is the most durable softwood grown in New Zealand making it highly suitable for panelling, weather boards and exterior joinery (Haslett 1986). Harvest age is likely to be around 40 to 45 years.

8.2.6 Coast redwood

Coast redwood occurs naturally in western North America on a narrow coastal belt (8-60 km wide) and c.720 km long between the Pacific Ocean and the first mountain range. Its home range

¹ Derrick Parry, Rangiora Nursery Ltd. Ph call. 13/06/2006.

² Don Tantrum, Wakanui Conifers, Email 21/06/2006.

³ <http://www.maf.govt.nz/statistics/primaryindustries/forestry/forest-resources/national-exotic-forest-2005/02-overview.htm#Species>. 18/07/2006.

extends from south Oregon to south of Monterey County, California, occupying around 700 000 ha. Coast redwood survives between sea level and 900 m altitude but is most abundant between 30 and 760 m on river flats or moister slopes. Initially introduced to New Zealand between 1860 and 1870 for amenity plantings it was established in State Forest at Rotorua c.1900 with mixed results. Appropriate site selection and preparation, and weed control are crucial factors for successful establishment of this species (Miller & Knowles 1993).

Fertile, sheltered sites with good rainfall are minimum requirements for coast redwood with seedlings and young trees very sensitive to low soil moisture and competition. Valley bottoms and free draining moist slopes are recommended, placing coast redwood in direct competition with Mexican cypress for sites in Cashmere Forest. Good quality heartwood of coast redwood is suitable for exterior joinery, exterior and interior cladding and weather boards, however the timber quality of fast grown coast redwood in New Zealand is known to vary widely (Miller & Knowles 1993). Harvest ages for coast Redwood are difficult to predict as this species responds quite differently to different sites. If good establishment and growth were achieved then harvest ages of around 70 to 80 years may be possible for trees > 60 cm DBH. Extended rotation ages for this species will result in increasing the proportion of heartwood in the tree and therefore the quality and durability of the timber (Miller & Knowles 1993).

8.2.7 Totara & Matai

Opportunities exist for the establishment of native podocarp species, in the production forest with the aim of timber production. The historic occurrence of totara and matai in the Port Hills environment and the presence of a high value market for their timber make them suitable options for native timber production. Bergin (1999) and Pardy *et al.* (1992) relate the importance of good establishment, early weed control and branch suppression for the production of high value trees. Light gaps in the canopy and the shade tolerance of native species creates options for establishment of small groups under an existing production canopy (nurse crop), this system of establishment addresses both weed control and branch suppression while promoting apical dominance. The long rotations in excess of 100-150 years that would be required to attain merchantable stems for these species means that consideration is required of siting and the

eventual harvest of surrounding shorter rotation, production forest. Site selection will be similar to coast Redwood and Mexican cypress.

It is envisaged that radiata pine will ultimately (200 years) occupy around 60% of the total plantation area (240 ha) of Cashmere Forest with alternative species making up the remainder of the area. Alternative species will generally be planted in moister, more sheltered sites on easier terrain. This will help to ensure good survival and growth and facilitate ground based harvest access necessary for CCM. More detail on site selection is presented later in this chapter.

8.3 Harvest Plan

8.3.1 Introduction

A harvest plan is an integral document for the success of any production forest management. This section outlines the objectives of the harvest plan and describes the various means by which forest harvesting in Cashmere Forest will be undertaken.

8.3.2 Harvest Plan Objectives

In order to efficiently capture and utilise economic return the management of harvesting operations is required within a formal harvest plan for Cashmere Forest. The management of harvesting operations needs to incorporate the following objectives:

1. Accurate temporal and spatial planning of harvesting, roading and landing placement and construction to allow efficient utilisation of funding while also aiming to maximise returns.
2. Demarcation of areas suitable for ground based or cable logging systems prior to harvest scheduling.
3. Planning of harvest coupe arrangement and sequencing within the harvest plan to allow resource planning, and auditing of cashflow exercises while also accommodating climatic constraints like wind.

4. Formalising road and landing location and subsequent construction requirements within the harvest plan.
5. Operating within regulatory and environmental limitations (Appendix 4; NZFOA 2006), management solutions listed above and the long term vision for Cashmere Forest.

8.3.3 Roothing

Roothing is a vital component of production forest management providing essential access for forest management and escape routes for forest users, but it is also costly and a major source of sediment production. The extension and upgrading of the current road network in Cashmere Forest is seen as a priority for the implementation of all other forest operations. All earthworks carried out in Cashmere Forest including road maintenance and construction will comply with national and regional guidelines incorporated into environmental guidelines (NZFOA 2006).

The significant costs associated with roading will be staggered in Cashmere Forest with the implementation of coupe harvesting. Coupe harvesting will allow the construction and cost of roading for a particular compartment to be spread over the first two harvest entries for that compartment. This is demonstrated in Table 8.1 where for example in Stratum1, haul road 16 is constructed before the first harvest visit, while construction of haul road 6 is postponed till the second harvest visit. Table 8.1 gives indicative costs per km of road construction within Cashmere Forest primarily determined by topography, slope and the condition of existing tracks. The reconstruction of all Main Tracks (Figure 8.1) is planned for the first year to satisfy an initial requirement for good access through the forest.

Proposed haul roads and landings (Figure 8.1) attempt to provide harvest and management access to the entire production forest. Road location will require updating by an experienced forest engineer within the formal harvest plan. Where possible haul roads will extend off and utilise existing tracks within the forest. Once the formal harvest plan is completed, construction can immediately begin on the Main Track to provide initial access for harvesting, and other forest management. All haul road and landing construction should be planned to take place at least one year before operational use is expected. This allows time for road materials to settle and road

compaction to occur. Annual roading plans will be required to ensure roading construction and maintenance is scheduled and performed to facilitate harvesting operations.

Table 8.1: Road and landing cost information for Cashmere Forest.

Stratum	Haul Road	Roading & Culvert	Landing	Total	Cost per ha	Cost per ha	
						1st coupe visit	2nd coupe visit
1	6, 16	\$56,723.60	\$4,000	\$60,723.60	\$1,327.58	\$378.74	\$948.84
2	12, 17	\$40,923.09		\$40,923.09	\$942.06	\$596.33	\$345.73
3	1, 2, 3, 18, 21	\$60,816.25	\$12,000	\$72,816.25	\$1,874.29	\$271.04	\$1,603.25
4	4, 5, 24	\$46,007.52	\$8,000	\$54,007.52	\$1,434.84	\$253.05	\$1,181.79
5	1, 14, 19	\$91,334.24	\$8,000	\$99,334.24	\$3,769.80	\$2,171.62	\$1,598.18
6	20	\$5,579.00	\$4,000	\$9,579.00	\$643.32	\$643.32	
7	15, 23	\$57,694.98	\$4,000	\$61,694.98	\$3,165.47	\$643.91	\$2,521.55
8	7	\$8,727.98		\$8,727.98	\$725.52	\$725.52	
9	8, 9, 10, 11	\$59,116.15	\$4,000	\$63,116.15	\$2,241.34	\$1,105.92	\$1,135.42
10							
Dfir	21, 22	\$42,529.33	\$4,000	\$46,529.33	\$2,792.88	\$937.70	\$1,855.17

Note: The cost for haul road 13 is included in the reconstruction cost of the main tracks. This reconstruction will be carried out in the first year.

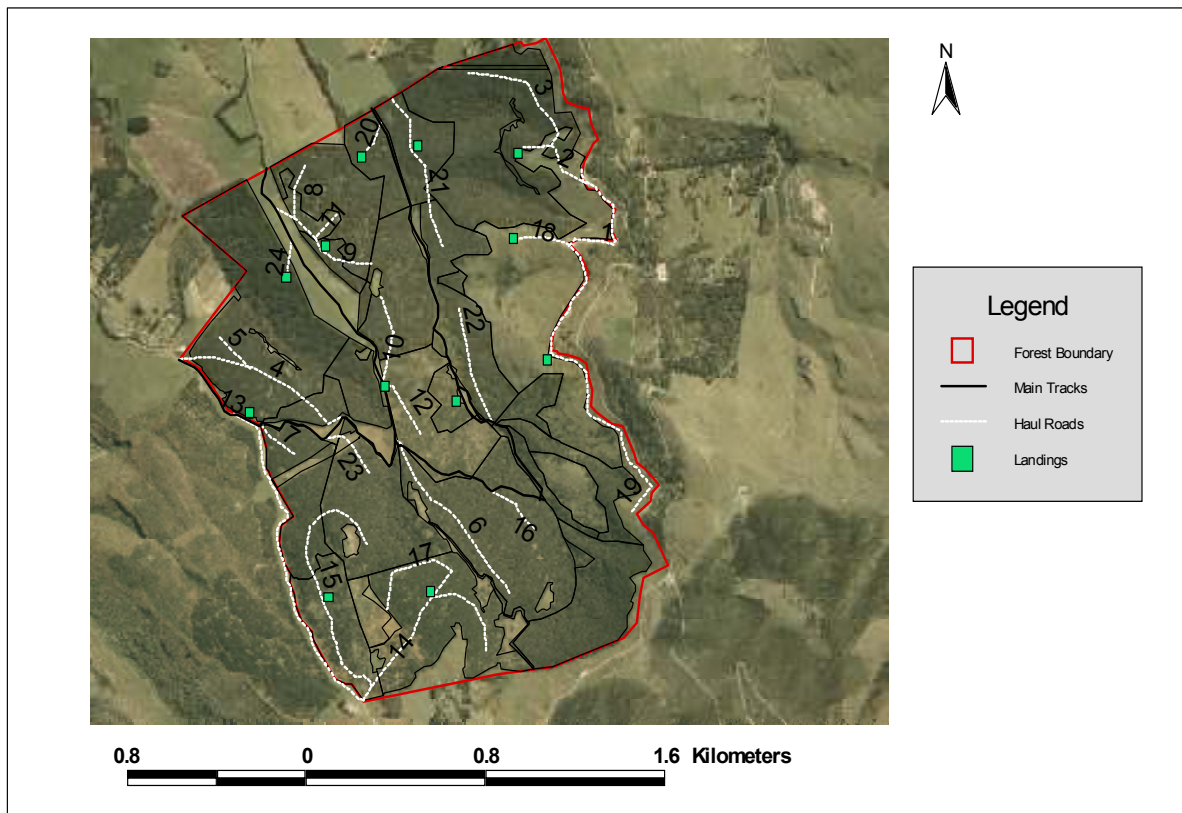


Figure 8.1: Potential locations of haul roads (numbered, refer Table 8.1) and landings for Cashmere Forest.

8.3.4 Landings

The construction of landings is a further significant earthwork cost that will be staggered with the implementation of coupe harvesting. As with roads, planning aims to minimise the number and extent of landings and delay construction till the year prior to implementation.

The small number and remote nature of landings (Figure 8.1) is in response to potential difficulty in landing establishment. OSH restrictions require landings to have a minimum size of around 40m by 40m. Establishing a site of this size on steep terrain is expensive and would require extensive earthworks and sediment management. The swing yarder system is suited to remote landings by its ability to bunch trees at the roadside where skidders can forward them to the landing site for processing. This method of harvesting is employed by Rayonier at Ashley Forest where a large stem truck is used for forwarding trees to the landing site. The purchase or hire of a

stem truck may be a future solution for Cashmere Forest if skidders prove uneconomic or unsatisfactory.

Environmental guidelines describe the management of sediment and runoff during construction and implementation of landing areas (NZFOA 2006). It is common practice under some forest management to re-establish landings in production forest; however in order to minimise environmental impact and cost of landing re-construction it is proposed that landings will remain clear of vegetation and serve a double purpose as information or focal points for recreational users.

8.3.5 Coupe Harvesting

The employment of coupe harvesting in Cashmere Forest is done primarily to reduce the visual and environmental impacts associated with clearfell production forest harvesting. Coupes of 2 to 5 ha will spatially and temporally separate harvesting operations within a stratum while also reducing the extent of the harvested area at any one time. Repeat forest entries under a coupe system for the harvest of one age class do result in increasing economic costs; this is seen as acceptable in consideration of the forestry, landscape, ecological and recreation goals for Cashmere Forest.

Coupe size, shape and location in the landscape will be determined by several factors, primarily compartment boundaries and natural topography. However, wind risk is also an important management consideration. In this context the strong southwest and northwest winds are of primary concern. In areas of general southwest or northwest aspect harvest coupes should move from the leeward side of the compartment to the windward side so that a new edge is not created each time a coupe is harvested (Smith *et al.* 1997; Somerville 1980). While this system creates a streamlining of wind over successive stands it does encourage turbulence on the leeward side of the residual mature trees which can damage the newly established trees. Where possible coupe harvesting should use natural topography to shield or reduce exposure to residual trees following the harvest of adjacent coupes. For example if southwest wind is funnelled down a valley or across a small saddle then coupe edges should not run perpendicular to this potential flow (Somerville 1980; Cremer *et al.* 1982).

Coupe size, shape and location will also be determined by the method of harvesting. In areas of cable harvesting coupes will extend from the road side to valley bottoms or adjacent harvest areas (Figure 8.2). This is done to avoid disturbing re-established areas with the hauling of harvested trees. In ground based areas with good road access coupes can have a more irregular arrangement and shape than in cable areas as access is improved.

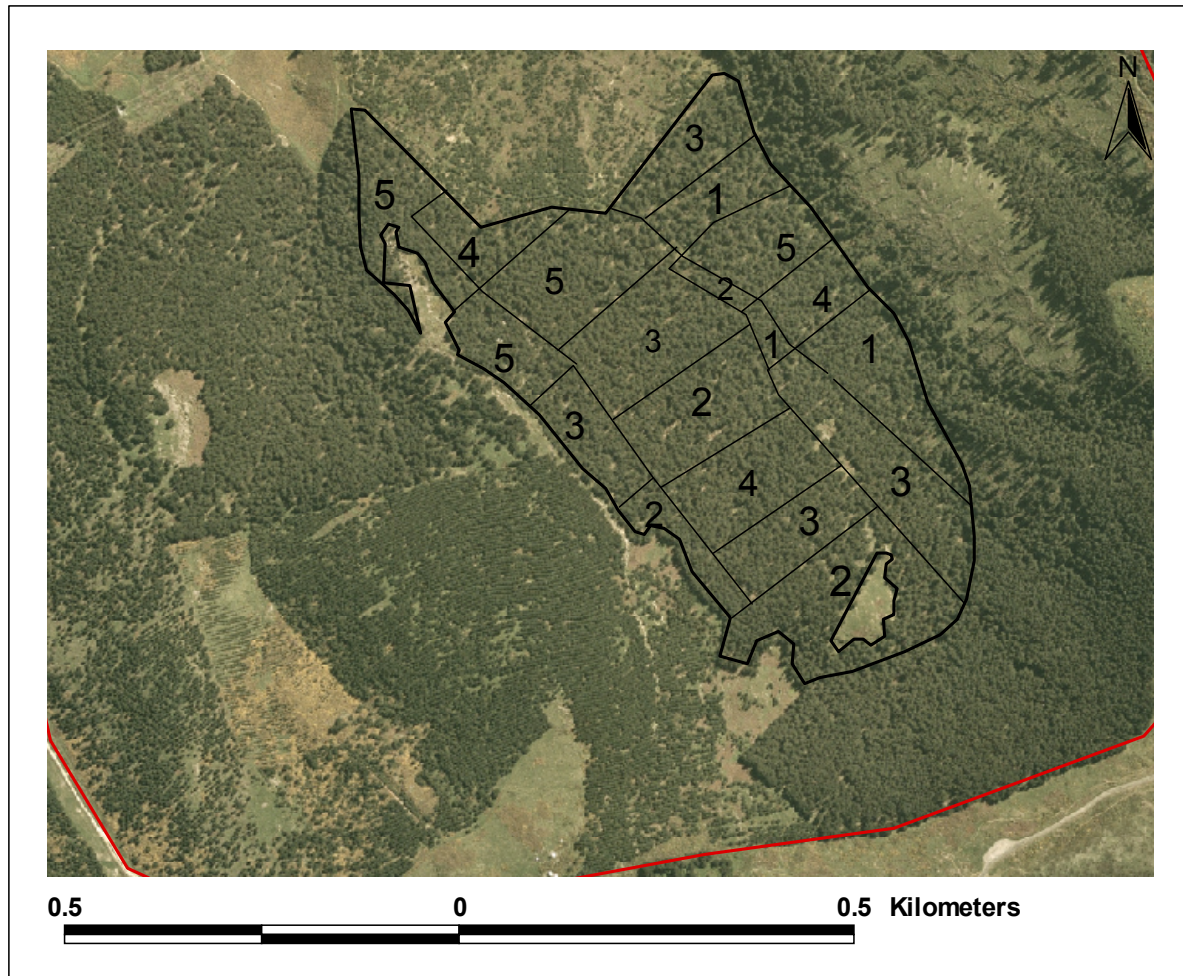


Figure 8.2: An example of possible coupe layout and year of harvest in compartment 8004.

Intended harvest return periods of between 2 to 5 years (Table 8.2) will result in some areas of edge exposure in adjacent stands, but the considerable operational advantages outweigh this. The implementing of 2 to 5 year return periods will concentrate operational activity temporally in an attempt to reduce cost and impact on other forest users. Because coupe harvesting does not have

annual harvest requirements this allows unnecessary road and landing construction to be delayed. This also reduces the impact of the costs of these operations by spreading them over a wider time frame. Annual harvest plans will be required to ensure harvesting operations are scheduled and performed efficiently and accurately according to the DFM plan .

Table 8.2: Aggregated harvest dates and areas for coupe harvesting in Cashmere Forest.

Stratum	Year of Harvest										
	2006	2011	2014	2017	2020	2022	2025	2027	2030	2035	2040
1	9.15	9.15	9.15		9.15		9.15				
2					8.69		8.69		8.69	8.69	8.69
3	7.77	7.77		7.77		7.77		7.77			
4			7.53		7.53		7.53		7.53	7.53	
5	5.27	5.27	5.27		5.27		5.27				
6		2.98		2.98		2.98		2.98	2.98		
7		3.898		3.898		3.898		3.898	3.898		
8				2.41		2.41		2.41	2.41	2.41	
9	5.63	5.63		5.63		5.63		5.63			
10					2.43		2.43		2.43	2.43	2.43
Dfir	3.33	3.33	3.33		3.33		3.33		27.938	21.06	11.12
Area (ha)	31.15	38.03	25.28	22.69	36.40	22.69	36.40	22.69	55.88	42.12	22.24

8.3.6 Harvest System

The choice of harvesting system in most forestry operations is primarily driven by terrain and cost. The availability of suitably skilled staff and machinery is also important and relevant to Cashmere Forest. Steep terrain and a desire to minimise road construction in Cashmere Forest require the use of cable harvest systems over significant areas. Ground based coupe harvesting will require staff experienced in working on sloping terrain while CCM areas demand skilled bushmen capable of directional felling and careful extraction.

Harvesting of steep or less accessible terrain with cable harvesting systems aims to employ a swing yarder cable system. The swing yarder system can operate at the roadside utilising central landings for processing. This reduces the cost of landing construction and provides flexibility in the spatial arrangement of harvest coupes. The economic maximum (250m) and average (150m) yarding distance of a swing yarder cable logging system¹ can be managed over most of Cashmere

¹ Email, Mark Grover, Forest Engineer, Rayonier, 30/03/06

Forest to compliment areas of easier terrain suitable for ground based machinery (Figure 8.3). While the maximum yarding distance will accommodate coupe harvesting in most areas of Cashmere Forest coupe size flexibility will be integral in making this operation feasible on steep challenging terrain. For example, target coupe sizes of 2 to 5 ha may need to be exceeded if terrain dictates certain areas can only be harvested from one vantage point. Good road placement will help alleviate this issue.

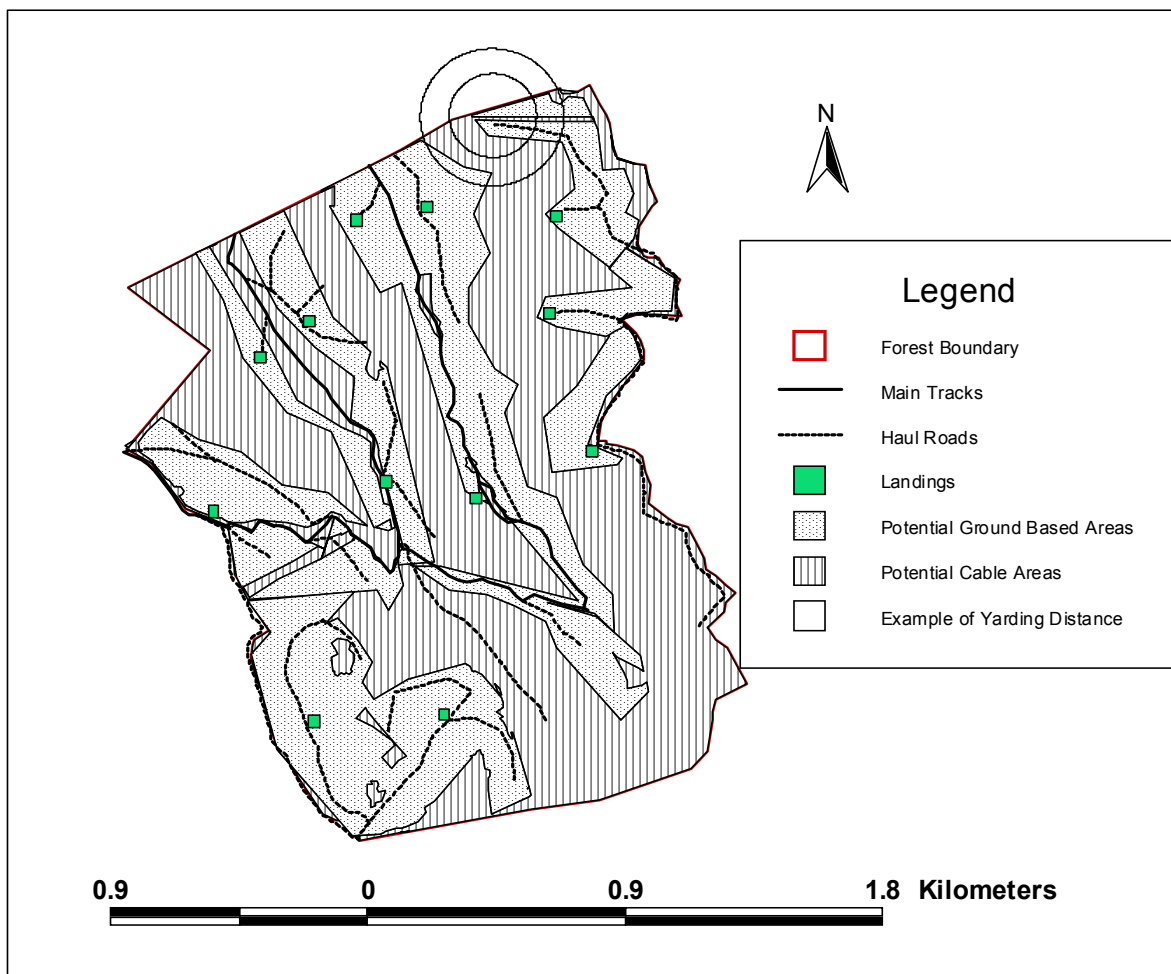


Figure 8.3: Proposed areas for ground based and cable harvesting and an example of the average yarding distance (inner circle) and maximum (outer circle) yarding distance for a swing yarder within Cashmere Forest.

The only area not covered by either system seen at the southern end of the forest in Figure 8.2 is within 500m of the three closest yarding points. This distance is outside the maximum yarding distance; however it is not implausible for a one-off harvesting situation. This area is proposed

for native restoration so that the extra tracking required to provide harvest access, across very steep terrain, would only be used once operationally.

The potential production area suitable for ground based operations amounts to around 50% of the production forest. Ground based coupe harvesting is proposed with a team using track skidders (TSK's). The use of TSK's, which are driven by a track system as opposed to wheels, has several advantages including the expansion of the area available for ground based operations and reductions in ground compaction and erosion. While ground based operations do result in increased soil disturbance and compaction over cable systems, they are necessary for the implementation of continuous canopy management. Ground based operations will utilise landings located in Figure 8.3.

8.3.7 Slash Management

Cable harvesting on steep terrain makes operations like delimbing extremely difficult to perform at the felling site. Whole trees are extracted to the road side where they will be forwarded to central landing sites. At the landing site delimbing will take place with the use of a static delimer; a stationary delimbing device that uses a machine like an excavator or bell loader to drag trees through delimbing knives. Retaining tree limbs throughout the forwarding process will have the added advantage of reducing the impact of dragged trees on road surfaces. Practicing good slash management like keeping waterways clear and maintaining access is fundamental to good forestry practice and stream health and is outlined in the New Zealand Environmental Code of Practice for Plantation Forestry (NZFOA 2006).

Considerable amounts of slash are created through this operation and it is suggested that this be transported to a suitable site where it can be utilised either as a fuel source for timber treatment processes or as a medium for garden compost. A certain amount of slash will be retained at the felling site as tree tops and branches inevitably break during felling and extraction.

8.3.8 Ground Based Areas

Initial demarcation of ground based areas is suggested in Figure 8.3, these areas will require updating on completion of annual harvest plans for each compartment. The area suitable for ground based operations is around 50% of the current production forest and is predominantly localised along proposed roadsides, and on easy terrain. The actual demarcation will not be as clear-cut as depicted, changing with access and topography. It is suggested that opportunities for ground based operations be maximised as the potential for continuous canopy management increases under this system.

8.3.9 Continuous Canopy Management

The nature of cable harvesting systems does not facilitate small group or single tree selection systems. The requirement for large haul corridors to allow tree recovery and the relative increase in cost over ground based operations means that cable systems do not achieve forest goals under this type of management.

Ground based systems are successfully employed in single tree selection of radiata pine by John Wardle on his property near Oxford. The proposed harvest system for Cashmere Forest aims to replicate that which occurs on the Wardle property. Initially tree selection is carried out on a diameter cutting limit where trees with DBH over 60cm are selected for removal up to c.20% of basal area. Removals begin at age 25 years at which time sufficient dominant trees will have reached the desired cutting limit. Directional felling is employed to harvest single trees from within a stand, sometimes utilising wedges or a skidder. Delimbing and log making are performed at the tree stump following which logs are skidded to an appropriate roadside landing. As delimbing and logmaking are carried out in the forest and extraction volumes are relatively small, the implementation of small roadside landings is possible.

Compartments 8101 (Stratum 3), 8602 and 8603 (Stratum 6) (Figure 8.4) have been selected for initial trialling of CCM for several reasons. Firstly, these compartments have been high pruned producing higher value trees, secondly they are in accessible areas of the forest and finally, most of the terrain is suitable for ground based machinery (100% in stratum 6 and c.68% in stratum 3).

A disadvantage of these areas for CCM is the dry exposed north aspect of some of the faces especially in compartment 8101. For this reason it is recommended that radiata pine remain as the predominant species on those faces.

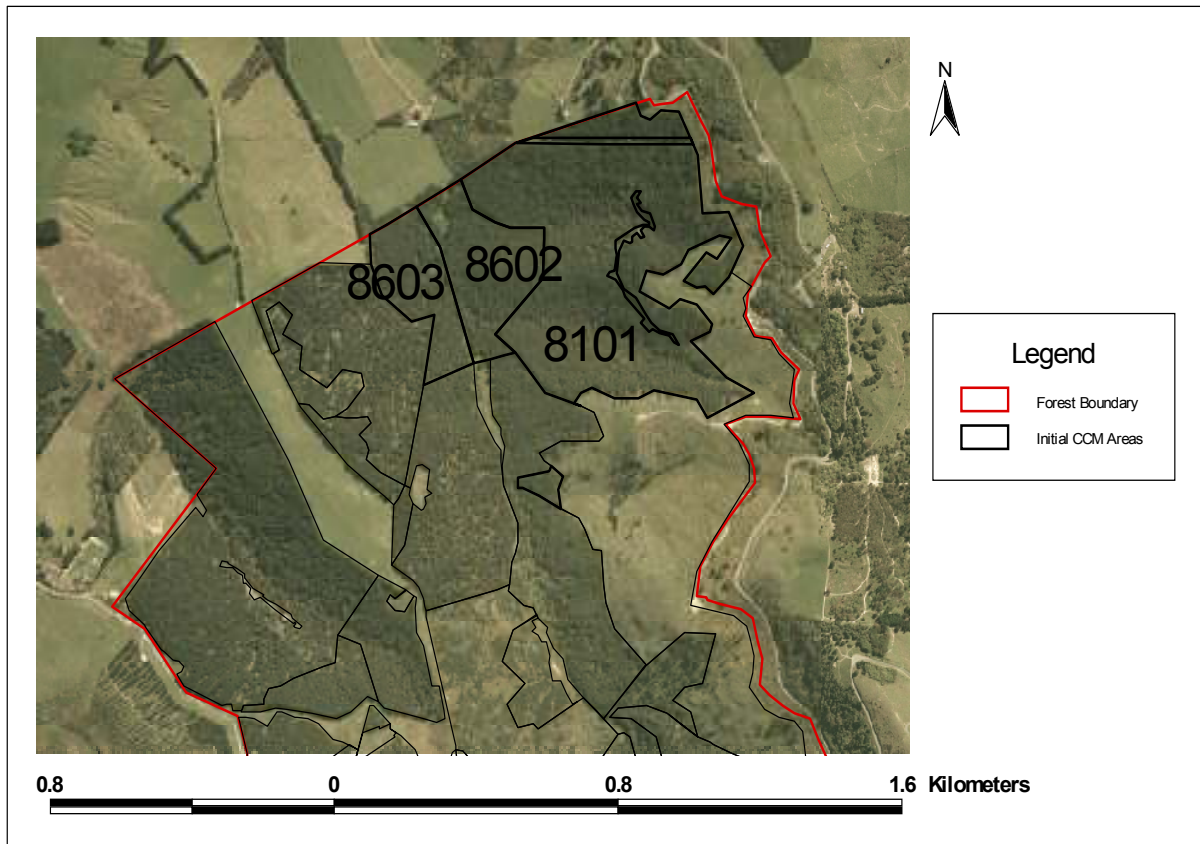


Figure 8.4: Proposed areas of Cashmere Forest for continuous canopy management.

Harvest visits to CCM areas are planned to coincide with coupe harvesting operations. During the first CCM harvest it is expected that the number of trees exceeding 60 cm DBH may be limited, however the timely removal of these trees is necessary to provide growing space for residuals. It is also expected that some waste thinning of very poor or malformed trees will be undertaken during the first harvest visit.

It is proposed that forestry contractors are only employed in CCM harvests that have suitably experienced bushmen and drivers. Payment of these teams contrasts to traditional methods; an hourly rate is employed so that staff focus on safety and residual stand health. Directional felling creates opportunities for hang ups and flying debris and therefore must be carefully planned and administered. Scarring of residual tree bark and subsequent reductions in growth and downgrade of timber are also consequences of hurried or inappropriate felling and extraction techniques.

8.4 Forest Measurement

8.4.1 Introduction

Auditing of growth, harvesting volumes, and cost and revenue predictions using real data is crucial to the long term sustainability of Cashmere Forest. To allow this, forest measurement systems require implementing to create an extensive forest information database.

8.4.2 Forest Measurement Objectives

The initial forest inventory for this management plan was carried out at an average c.2.2% intensity using bounded circular plots laid out on a c.100 m grid. Further measurement of these plots and establishment of additional plots in unmeasured areas is required to facilitate database creation. Future forest measurement will need to satisfy three main priorities.

1. Auditing of growth and harvest predictions through pre-harvest inventories.

To do this PSP's established during the forest inventory (summer 2005/2006) will require re-measuring in a pre-harvest inventory to audit growth and harvest volume predictions. Plot re-measurement will be carried out in appropriate coupe areas one year prior their planned harvest. These re-measurements will be used as a sub-sample of the original measurements to evaluate growth in the interim and adjust harvest predictions harvest coupes.

2. Assessment of the current unmeasured production estate (planted post 1997).

PSP's will need to be established where appropriate in previously unmeasured production forest areas (planted post 1997). Circular bounded plots will be used established at an intensity of around 1%. Initial and ongoing measurement of these plots will provide consistent records of forest growth, health and silvicultural treatment of these forest compartments. This standard of forest inventory will also be implemented in future re-established production areas ensuring good long term forest information and planning.

3. Auditing of all cost and revenue predictions surrounding forest harvesting and transport.

The collection and collation of all harvest information (harvest volume, total recoverable volume, harvest and transport costs and revenue) is essential for auditing of those figures generated in the initial modelling process. This information will be directly available through contractor quotes, receipts and return documents.

8.5 Silvicultural Regime

8.5.1 Introduction

The implementation of an appropriate silvicultural regime is crucial to realising good economic value from the production forest. An appropriate silvicultural regime for Cashmere Forest will reflect environmental conditions of the site like weeds and wind while also achieving the desired end product of a high value production forest. This end product is capable of off-setting increased management costs due to coupe harvesting and continuous canopy management.

8.5.2 Proposed Silviculture Regimes

Table 8.3 outlines the proposed silvicultural regimes for radiata pine and other alternative species in Cashmere Forest. The radiata pine silvicultural regime is an intensive management regime designed to facilitate high value timber production. This is different to traditional regimes carried out on most of the current stands in Cashmere Forest and the Canterbury region. This is designed as a starting guideline and will require regular review as the effectiveness of initial stockings and treatments becomes evident. All silvicultural activities within the production forest will operate within environmental guidelines (NZFOA 2006). Annual plans for silvicultural operations will be required for scheduling and performing of relevant silviculture operations.

Table 8.3: Initial silvicultural regime for the re-establishment of radiata pine.

	Radiata pine - pruned sawlog regime (Coupe/Cable logged)
Year 0	Plant 1200 stems per ha.
Year 6-7	Prune to 2.5 m and waste thin to 800 stems per ha.
Year 9-10	Prune to 4.5 m and waste thin to c.500 stems per ha.
Year 12-13	Prune to 6.5 m
Year 25-45	Coupe harvest with cable system
	Radiata pine - pruned sawlog regime (Small group/Ground based logging)
Year 0	Plant 1200 stems per ha.
Year 6-7	Prune to 2.5 m and waste thin to 800 stems per ha.
Year 9-10	Prune to 4.5 m and waste thin to c.450 stems per ha.
Year 12-13	Prune to 6.5 m
Year 25-45	Small group/Single tree selection with ground based system
	Douglas fir
	Plant 1200-1300 stems per ha.
Year 15-20 or MTH 16-17m	Thin to c.600 stems per ha. (Production or waste depending on market at time)
Year 50-80	Small group/Single tree selection with ground based system
	Eucalypts
Year 0	Plant 1100 stems per ha.
Year 5-6*	Prune to 4.5 m and waste thin to c.500 stems per ha.
Year 15-17*	Prune to 6m and waste thin to final crop trees of c.200 stems per ha.
	*Thinning operations should coincide with canopy closure or predominant mean height of 10 and 16 m respectively.
Year 35-55	Small group/Single tree selection with ground based system
	Mexican cypress
Year 0	Plant c.1500 stems per ha.
MTH 5m	Prune to 2m and waste thin to c.600 stems per ha.
MTH 9m	Prune to 4m and waste thin to 200 stems per ha.
MTH 13m	Prune to 6m
MTH 30m	Small group/Single tree selection with ground based system (Year 35 to 40 onwards)
	Redwoods
Year 0	Plant at 1:6 mixture with other conifer species at c.3m centres
	Aim for 250-300 sph and prune 8-10m
Year 70-80 on	Small group/Single tree selection with ground based system

8.5.3 Site Preparation

Ground preparation before re-establishment will be minimal in this environment due to the steep terrain and erosion risk associated with the loessial soil. Minimising soil disturbance, sediment production and run off while also retaining soil and foliage nutrients are important goals of forest management. Therefore, seedling establishment will occur on largely unaltered cutover sites.

8.5.4 Weed Control

Plant pests pose the greatest threat to production values during the establishment of production species. Providing a site clear of weed competition dramatically increases the initial survival and growth of production species (Watt *et al.* 2003; Richardson *et al.* 1993; Mason *et al.* 1996). The timing of harvest operations is important when considering weed control prior to establishment.

Seasonal restrictions on establishment operations and their temporal separation from harvesting activities inevitably results in the establishment of weeds on cutover sites. Pre plant desiccation spraying and post plant releasing are recommended as an effective means of combating weed establishment in this region¹. The timing of harvesting operations will effect weed germination and subsequently the effectiveness of desiccation spraying. If harvesting occurs before autumn then significant germination and growth of weed species will occur to allow a good aerial desiccation spray prior to planting in winter/spring. However if harvesting occurs during autumn, colder weather will suppress weed germination and reduce the effectiveness of desiccation spraying in the following planting season. Under these circumstances it may be better to wait one more year before desiccating and replanting.

An aerial release spray using a chemical that does not affect crop trees will most probably be required in the following year to reduce further weed germination and competition. This spray regime will only be suitable in coupe areas large enough to accommodate a helicopter as harvest residue and terrain will limit ground based spraying. In small coupes manual spraying using strip or spot spraying methods may be required to achieve sufficient weed control. Pre and post plant applications are still recommended for ground based spraying.

¹ Email, Simon Rapley, Forester Rayonier 15/03/06

Relatively high initial stockings across all species (Table 8.2) are also chosen partially in response to weed control. High stockings will lead to early canopy closure and suppression of invasive weeds.

8.5.5 Fertiliser

Requirements for fertiliser will need to be assessed following foliar analysis over the first two years of operations in Cashmere Forest. Fertiliser application aims to improve tree health and growth on otherwise nutrient deficient sites. The loessial soils of the Port Hills are described by Griffiths (1974) as having moderate fertility and as such may require little nutrient application. The application of Boron is commonly undertaken by local forest owners SPBL on Canterbury foothill sites of known Boron deficiency and this may also be required at Cashmere Forest depending on test results.

8.5.6 Radiata pine

Establishment (Coupe areas)

Establishment will be carried out on a largely unaltered cutover site. Planting will be carried out in late winter or early spring to exploit elevated soil moisture at these times. Initial stockings outlined in Table 8.2 are proposed to be planted into the southwest or northwest where exposure to these winds occurs. Good nursery, transplant and establishment practices are essential to improve early growth and survival and reduce toppling.

Establishment (CCM areas)

Harvest sites should be monitored within CCM areas for the natural regeneration of radiata pine. If no natural regeneration is occurring following the second harvest cycle than manual planting should be carried out. Within these areas, the re-establishment of radiata pine should be limited to relatively dryer sites, exposed ridge tops, shoulders and north facing areas leaving the moister sheltered sites for alternative species.

Pruning and Thinning

The suggested timing of pruning and thinning activities is outlined in Table 8.2. Three pruning lifts aim to maximise economic return through the production of clearwood. Two thinning removals and a relatively high final crop stocking aims to minimise windthrow risk and retain management options. Growth will have to be monitored through initial rotations to ensure that the high final crop stocking is not significantly impacting diameter growth. In areas suitable for ground based operations a final crop stocking of c.500 stems per ha. should be employed to maintain stockings through the early removal of crop trees (>60 cm DBH) under CCM. In steeper terrain where coupe areas will be cable harvested, slightly lower final crop stockings of c.450 stems per ha. are employed.

It should be noted that high stockings are not ideal for creating good tree wind resistance, the larger thinning removals required with high initial stockings also creates windthrow risk in the future (Smith *et al.* 1997; Somerville 1980; Cremer *et al.* 1982). These factors are balanced by advantages of high stockings including weed suppression, the mutual benefit provided by closely spaced trees, smaller branch size, apical dominance and less taper.

8.5.7 Douglas fir

Establishment (Coupe areas)

Establishment in suitable coupe areas is accomplished with a regime employing moderate initial stockings (Table 8.2)¹² to balance site occupancy and intraspecific competition for soil moisture and nutrients. Suitable areas will generally be south or southwest facing along valley sides or bottoms.

¹ Email, Marcel van Leeuwen, Forest Technician, SPBL, 16/05/06.

² <http://www.tussocks.net.nz/forestry/species/Douglasfir.html> 20/06/2006.

Establishment (CCM areas)

The shade tolerance of Douglas fir creates the opportunity for establishing this species under mature canopies. This would be feasible in compartments 8101, 8602 and 8603 where CCM is to be trialled. Establishment of seedlings on suitable sites in small group clearings can proceed on creation of gaps and an increase in light levels. Sufficient seedlings should be established to ensure site occupancy and survival of final crop trees.

Pruning and Thinning

The high cost of pruning and branch die-off below the canopy exclude the requirement for this treatment in Douglas fir. Two waste thinnings are outlined in Table 8.2. The first waste thinning should remove poor or malformed trees and create growing space for residuals. The second waste thinning may be a production thinning if markets and prices are amenable. Both thinning operations will produce opportunities for public firewood collection.

8.5.8 Eucalypts**Establishment (Coupe areas)**

Establishment of eucalypt species will be carried out on valley sides and bottoms in sheltered sites with mixtures of *E. fastigata* and *E. obliqua* grading into solely *E. fastigata* at higher elevations. An initial stocking for eucalypt establishment is outlined in Table 8.2. Weed control and frost avoidance is important for good initial survival of eucalypt seedlings. Therefore pre-plant spraying and releasing are essential, Miller *et al.* (2000) also recommend application of nitrogen and phosphorus fertiliser's c.1-2 months following planting. Fertiliser application should be implemented on a trial basis in early plantings.

Pruning and Thinning

To produce high value clearwood timber, pruning is required up to c. 6m. While pruning is scheduled for two visits (Table 8.2) branching should be monitored as some natural branch shedding may occur and branch size must be limited to < 2.5 cm to avoid large dead knots. The removal of large steep branches above 6 m is also important for good tree form and sawn timber production. Pruning operations should be carried out in fine weather to promote stub drying which decreases the risk of fungal infection.

The first thinning operation aims to remove poor or malformed trees and create growing space while the second visit further reduces the stand to a suitable final crop stocking. Thinned trees from both thinning operations would be suitable for public firewood collection.

8.5.9 Mexican cypress

Establishment (Coupe areas)

High initial stockings (Table 8.2) are required to ensure site occupancy, weed suppression, branch size regulation and good form in this species which has relatively slow initial growth. Requirements for moist deep fertile soil will limit establishment to south or southwest facing toe slope areas adjacent to riparian strips or in gully bottoms.

Establishment (CCM areas)

The predominant establishment of Mexican cypress will be in CCM areas where a mature canopy will minimise issues around weed competition and site occupancy. The relative shade tolerance of Mexican cypress will allow establishment of seedlings in larger harvest gaps which promote good stem form and regulation of branch size. As with coupe areas, establishment will be in southerly facing, toe slope areas adjacent to riparian strips or in gully bottoms.

Pruning and Thinning

The three pruning visits outlined in Table 8.2 may need increasing to ensure timely removal of large branches. Miller and Knowles (1992) describe the initial need for light, frequent pruning to avoid the formation of dead knots in the bottom log. The crop selection of trees with horizontal branching also reduces the likelihood of grooves and flanges occurring in butt logs.

The windthrow risk inherent with Cashmere Forest is increased due to shallow rooting typical of Mexican cypress (Miller and Knowles 1992). While three thinning visits aims to address this issue by retaining mutual support and reducing canopy opening characteristic of two large thinnings, it will result in an increased rotation length due to the onset of intraspecific competition.

8.5.10 Coast redwood

Establishment (CCM areas)

The establishment of coast redwoods is recommended under a nurse crop and will be limited to areas under CCM. As with Mexican cypress, establishment will be in southerly facing toe slope areas adjacent to riparian strips or in gully bottoms in smaller canopy gaps. Sufficient seedlings should be established to ensure site occupancy and good final crop trees. A final crop stocking of c.250 stems per ha is desirable.

Pruning and Thinning

As with Mexican cypress but to c.8 m.

8.5.11 Totara & Matai

Establishment (CCM areas)

The establishment of totara and matai will also be limited to within areas under CCM to address requirements for weed control and shelter. Bergin (1999) also highlights the need for the exclusion of browsing animals and the use of high quality seedlings (50-80 cm) for successful totara establishment. Where high survival is expected, a plant spacing of 4-5 m within a nurse cover will give an approximate stocking of 400-500 stems per ha. (Bergin 1999). While totara and matai will require sites similar to those suitable for Mexican cypress and coast redwood the natural occurrence of these species should allow expansion of this small site window.

Pruning and Thinning

Pruning has been trialled successfully in totara although there is no evidence that it improved form or clearwood recovery. The establishment under a mature canopy will reduce the necessity for pruning and is therefore only prescribed for large branches which will obviously result in significant downgrade of logs. Thinning should be carried out to remove poor or malformed trees and ensure good final crop trees.

Figure 8.5 shows amended forest area (c.218.3 ha) and boundaries following indigenous restoration and south facing, sheltered areas suitable for the future establishment of alternative species. Alternative species include Douglas fir, coast Redwood, Mexican cypress, matai and totara. Pine/Eucalypt areas (Figure 8.5) are zones suitable for both species although it is envisaged that species will be established as monocultures within these areas.

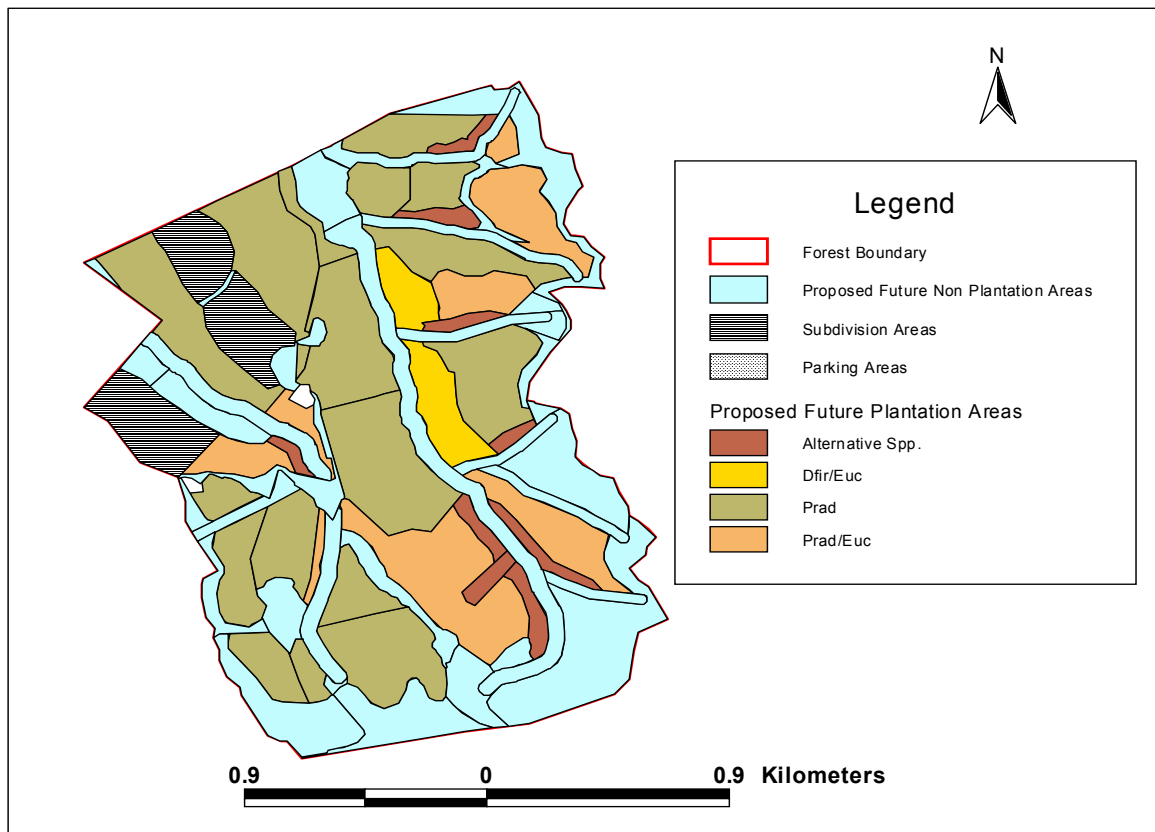


Figure 8.5: Proposed future plantation areas for Cashmere Forest.

Chapter 9

Environmental Management

9.1 Introduction

This section provides an outline of the approach to environmental management within Cashmere Forest. Environmental management covers planned improvements to landscape values by establishing riparian areas, minimising erosion and enriching the forest canopy, and the general approach to indigenous restoration and associated species choice. Pest management is also described, covering both plant and animal pests likely to threaten biodiversity in Cashmere Forest.

9.2 Landscape

9.2.1 Introduction

This section aims to describe the methods by which the levels of indigenous and exotic biodiversity within Cashmere Forest will be increased. At present indigenous biodiversity is limited by the small extent and poor ecological condition of non plantation areas. Exotic biodiversity has also been neglected due to a solely production focus in historic management of the forest. Improving biodiversity will be achieved by extensive indigenous restoration in non plantation, riparian and selected cutover areas, establishing exotic amenity plantings and introducing alternative production species.

9.2.2 Streams and Riparian Areas

The detrimental effects of production forest management on stream life are well documented in Graynoth (1979) and Boothroyd *et al.* (2004). Introduction of slash and debris, elevated temperatures, stream blockages, increased sediment, nutrients and contaminants can all result

from land preparation, roading, weed control and harvesting operations when they are not done within appropriate guidelines. Sediment production from roading and harvesting is especially relevant in Cashmere Forest where steep terrain facilitates the down slope movement of sediment into waterways (McIntosh & Laffan 2005; Carling *et al.* 2000; Megahan & Kidd 1972). The establishment of riparian areas of native restoration along most streams aims to address this issue as well as establishing habitat for native biodiversity.

Establishment of the current production forest has resulted in production species planted along and right up to stream edges. To facilitate the restoration of riparian areas these trees will be removed. While regional controls exist on mechanical vegetation clearance within 10m of a waterway (Appendix 4) the management controls on forest harvesting within the forest harvest plan and intended native restoration of the area should see the harvesting of these trees be allowed. Coupe harvesting will ensure extensive riparian areas are not exposed at any one time and riparian status will ensure minimal interference following native establishment.

The future protection and restoration of stream environments is a primary objective of the management of Cashmere Forest. Riparian plantings of native restoration are important components of the future non plantation areas of forest. Riparian reserves will extend the native areas throughout Cashmere Forest and provide connectivity to adjacent park and forest areas while also enriching the visual landscape of the forest. Planned riparian areas along Worsleys Stream and Cashmere Stream are to be a total of 60 m wide with riparian areas along subsidiary streams a total of 40 m wide, totalling c. 41.6 ha. A 60 m wide riparian area extends 30 m each side of the centre line of the stream providing ample space for multiple recreational tracks. The width of these areas may be large in a production context; however the strong ecological and recreational goals for the forest drive their implementation.

An excellent opportunity exists to employ local students to survey current stream flora and fauna and record changes as riparian areas are extended along the stream network providing invaluable data for future management of streams within the forest.

9.2.3 Erosion

The retention of stumps in cable logging areas and of stumps and slash in ground based areas aims to reduce soil erosion and retain nutrients in cutover sites. Stumps provide mechanical strength to the soil both laterally and vertically through root growth. The retention of slash and litter returns nutrients to the soil while also protecting it from splash erosion.

Previous salvage operations following storm damage in the mid 1990s and 2000 have resulted in the siltation of several dams within Cashmere Forest. Remedial construction work and native restoration will augment the riparian environment while also providing limited ground reservoirs of water for fire fighting.

Forestry road and landing construction have historically been primary sources of sediment in forest streams. All earthworks undertaken within Cashmere Forest will follow environmental guidelines (NZFOA 2006) which propose to minimise environmental consequences of these operations.

9.2.4 Forest Canopy

Further enrichment of the Cashmere Forest landscape will be achieved through the establishment of the alternative production species outlined in Chapter 6, amenity plantings of non production exotic species and the restoration of current and future non plantation and riparian areas. The implementation of coupe harvesting and CCM will also improve landscape values.

Alternative production species will break the canopy monotony common to production forests in New Zealand. By creating significant areas of alternative species biodiversity within the production forest will increase due to the evolution of more diverse habitats between and within the different species.

Amenity plantings of other exotic species such as larch, cedar, fir, oak, plane and elm trees around designated public areas like car parks, picnic areas, main thoroughfares and other focal points will serve to further diversify the forest canopy and habitat resource within Cashmere

Forest. Species selection will reflect those exotic species that are presently growing successfully in nearby parkland e.g. Victoria Park.

The restoration of current and future non plantation areas will also serve to diversify and improve the visual impression of Cashmere Forest while also significantly enhancing the native biodiversity.

9.3 Indigenous Restoration

9.3.1 Background

Indigenous restoration and regeneration currently occupy large areas of the Banks Peninsula region; indigenous restoration within Cashmere Forest aims to augment regional work by creating connectivity at a local scale between adjacent restoration areas and improving indigenous biodiversity in the forest. For indigenous restoration to be successful it will require good planning, the selection of suitable species and appropriate solutions to issues like weeds that are inherent to this site.

9.3.2 Restoration Planting Approach

Restoration plantings within Cashmere Forest aim to significantly increase the levels of native biodiversity in the forest. This will be accomplished on a number of fronts including expansion and active restoration of some current non plantation areas (Figure 9.1), establishment of riparian areas and establishment of new restoration in cutover production areas (Figure 9.2).

Initial restoration in current non plantation areas will concentrate on clearings and tracks. These areas have relatively little existing native vegetation in comparison to bluff areas and are likely to be highly visible to recreational users. As coupe harvesting commences to clear production forest from stream areas and proposed future non plantation areas, restoration of these areas will begin. The considerable expense of restoration will limit the area of restored land from year to year.

Initial priority will be given to the establishment and restoration of riparian areas due to high recreational use, likely restoration success and the connectivity network riparian areas will provide between other non plantation areas.

Restoration in Cashmere Forest will not be undertaken in homogenous conditions but will follow some overriding principles:

- Species selection will be of native plants found in the Banks Peninsula Ecological District which are adapted to local conditions.
- Planting is to be carried out from late winter to early spring. This will help to avoid frosts while exploiting high soil moisture at these times.
- Appropriate use of mechanical clearance and/or herbicide use to clear planting sites and reduce grass competition for seedlings. Weed mats will be placed around each seedling to help reduce weed re-establishment as required.
- Release weeding or spraying may be necessary in subsequent seasons to minimise plant death due to water, light and nutrient competition.

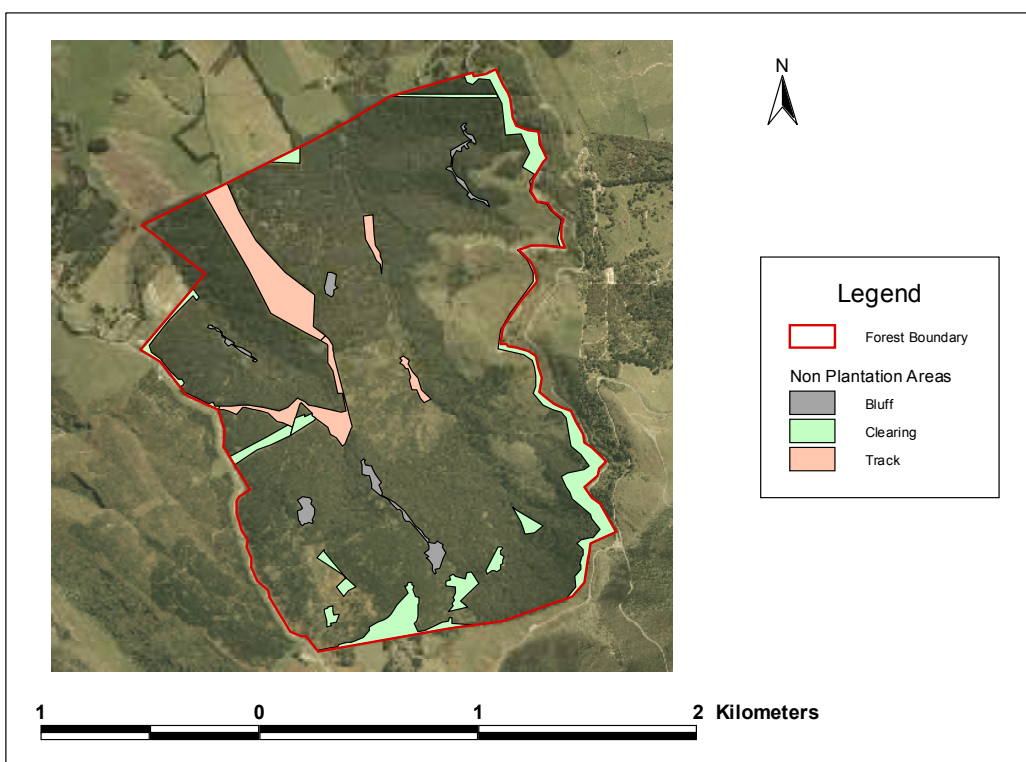


Figure 9.1: Current non plantation areas in Cashmere Forest (42.8 ha).

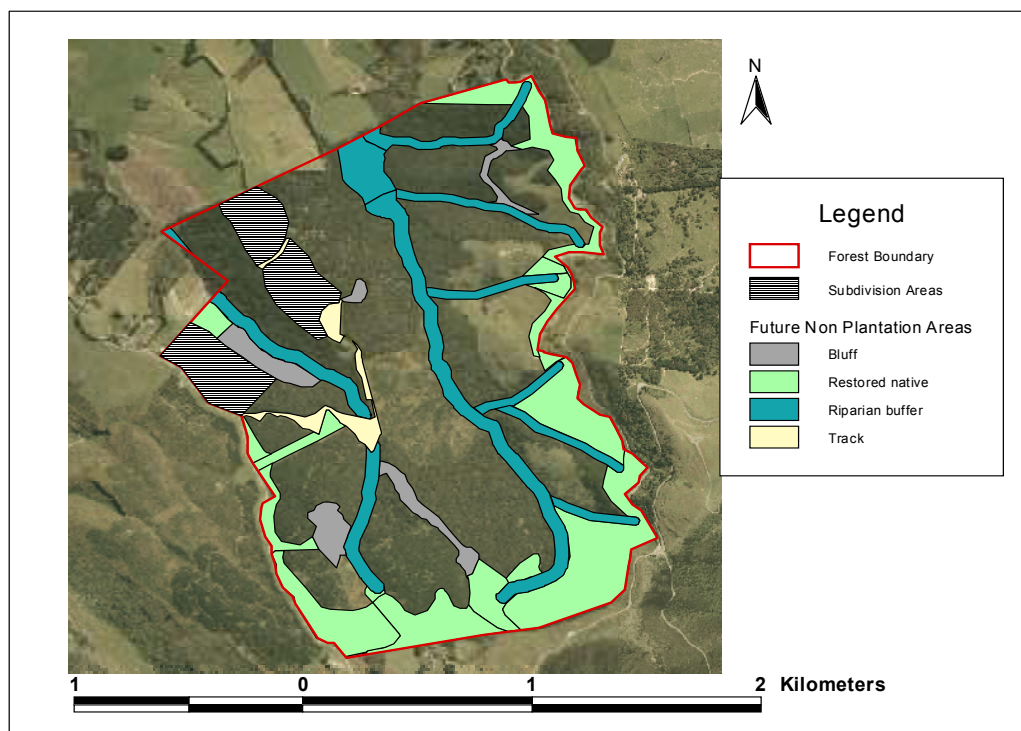


Figure 9.2: Proposed future non plantation areas in Cashmere Forest (138.7 ha including riparian).

9.3.3 Species Choice and Placement

Historic accounts of podocarp forest on Banks Peninsula (Wilson 1992) and more specifically in the adjacent Hoon Hay Valley (Ogilvie 1978) are important drivers of restoration species selection. This information is combined with existing species lists for the Port Hills area and recent surveys of non plantation areas found in Cashmere Forest. Species will be selected from these pools which are adapted to local conditions and have good growth and historic establishment success in other local restoration projects. Species selection must also provide the right habitats and resources for increasing native biodiversity namely the attraction of seed dispersing birds.

Table 9.1 provides an initial list of species appropriate for restoration of non plantation areas. It is expected that this list will be expanded and updated as restoration proceeds, some species may need to be replaced following poor restoration success. As most of these species are growing in Cashmere Forest, removal from the list would be due to poor initial growth and competition induced failure. As the selection of species is reviewed so should the approach to planting and site preparation to highlight any short comings in these operations.

Planting stock for restoration plantings should all be sourced from within the Banks Peninsula Ecological District. CCC experience with other local restoration projects will provide valuable information surrounding species selection, sourcing of seedlings and site preparation.

Table 9.1: Species list of some typical trees and shrubs found in Cashmere Forest and likely additional restoration species.

Species found in Cashmere Forest	Bluff	Clearing	Track	Riparian
small leaved Coprosma spp.	x	x		
karamu		x	x	x
cabbage tree	x	x	x	x
tree fuchsia	x	x	x	x
broadleaf	x	x	x	x
mahoe	x	x	x	x
kohuhu		x	x	x
SI kowhai	x	x	x	x
matagouri	x	x		
porcupine shrub	x	x		
red matipo	x	x		
flax	x	x	x	x
kanuka	x	x	x	
five finger	x			
prostrate kowhai	x			
silver tussock	x	x	x	
pohuehue	x	x	x	
Likely additional restoration species				
totara		x	x	x
matai		x	x	x
kahikatea		x	x	x
<i>Olearia</i> spp.		x	x	
Hebe spp.	x	x	x	x
manuka	x	x	x	

The appropriate siting of species is important in the Port Hills area where summer droughts are common and soil moisture gradients are markedly different between exposed ridge tops and valley bottoms. An example of this is where species like matagouri, pohuehue and kanuka which can cope with dry conditions are utilised along drier areas like ridge tops and shoulders. Across the moisture gradient there are subtle microclimates in sheltered gullies and hollows and moister south facing areas which can result in expanding the list of potential restoration species.

Therefore, it is important to gain a complete understanding of the topographical influences on site within Cashmere Forest for good restoration success.

9.3.4 Establishment

There will be three broad scenarios under which restoration plantings will be established including:

1. In current non plantation areas where a grass sward is present. This will require mechanical clearance and/or herbicide use for initial clearance of the grass sward. The need for further releasing should be reviewed in the spring following establishment for these areas.
2. In non plantation areas where gorse or broom is present. This will require the mechanical clearance of planting strips through the gorse/broom to allow access and planting sites. Further mechanical clearance or herbicide application may be required to expand planting sites and reduce weed competition. The need for further releasing should be reviewed in the spring following establishment for these areas.
3. In designated cutover areas. The onset of mass weed germination following disturbance and the relatively slow growth of indigenous species will result in poor restoration success in these areas. Aggressive growth of weed species will lead to overtopping and smothering of restoration plantings established with traditional strip or spot spraying techniques.

It is proposed that a series of trials be implemented in cutover areas to test the effectiveness of different restoration methods aimed at addressing these issues. The initial weed control treatment in cutover areas would reflect practices employed for re-establishment of production species in coupe areas. Blanket desiccation would be carried out following harvest when the mass germination and establishment of a woody weed crop occurs. Subsequent to this three trial methods are suggested.

- Restoration plantings will be undertaken following blanket desiccation with spot release spraying in the following year.
- Sowing of a mixture of indigenous and exotic grasses or legumes like clover to gain site occupancy following blanket desiccation. Grasses will limit further woody weed establishment and be easier to manage in restoration plantings. This option may be appropriate in large coupes where funding may not be available to restore the entire coupe at one time.
- Sowing of a mixture of poroporo and kanuka seed either prior to harvest or post blanket desiccation of the emergent weed crop. Poroporo and kanuka are both pioneers, they are able to gain site occupancy relatively quickly, they are present at the site, and seed is in good

supply. If this method is successful in suppressing weed growth and gaining site occupancy then enrichment plantings of further indigenous species will be undertaken in subsequent years.

Weed mats will be utilised under all scenarios to reduce competition in areas immediately adjacent to planted seedlings. Under scenarios 1 and 3 seedlings will be spaced at 1.5 m centres with podocarps at 3 m centres in appropriate sites. In scenario 2 planting strips aim to accelerate succession of gorse and broom, one or two lines of seedlings will be planted per strip. Appropriate species like flax will attract seed dispersing birds to further native regeneration under the gorse/broom canopy.

9.3.5 Risk

Restoration areas and Cashmere Forest as a whole is very susceptible to damage by fire. Public road access along two sides, vantage points above Cashmere Forest and unrestricted user access present opportunities for ignition. The implementation of a total fire ban within the forest boundary and maintenance of grass road sides along Dyers Pass Rd and Summit Rd will help to reduce the risk. Water reservoirs in the form of dams and concrete tanks exist within the forest for small scale ground based fire control. Further details of fire management are described in the recreational management plan for Cashmere Forest.

9.4 Recreation

Recreation is a primary purpose for the purchase and implementation of the Cashmere Forest Park concept and as such it is considered in all forest park management decisions. Forest management operations within the production forest will be planned to avoid important recreation dates and minimise impact on recreational users. This will be achieved by:

- maintaining personal contact between recreational user groups, the CCC and production forest managers;
- concentrating harvesting and silviculture operations every 2 to 5 years;
- providing information for recreational users on upcoming forest operations;

- regular forest inspections to identify hazards like windthrow that may impact recreational track access.

Recreation is discussed in more detail in the separate Recreation Plan.

9.5 Plant and Animal Pest Management

9.5.1 Introduction

A comprehensive weed and pest management strategy is crucial for control of exotic plant and animal pests within Cashmere Forest. Exotic plant pests pose serious threats to the economic viability of commercial plantation establishment. The successful establishment, restoration and regeneration of appropriate indigenous species will also only occur following exclusion and/or removal of invasive plant and animal pests, which includes domestic stock. The initial setup of a pest management strategy is intensive and inherently expensive but is crucial for forest visions and goals to be realised.

9.5.2 Objectives of Pest Management

Pest management within Cashmere Forest is driven by four broad objectives which are:

- to reduce the impact of biosecurity threats on production values within Cashmere Forest;
- to reduce the impact of biosecurity threats on indigenous biodiversity values within Cashmere Forest;
- to prevent the introduction of new biosecurity threats to Cashmere Forest;
- to maintain communication with adjacent public and private land owners, and recreational users about biosecurity management issues.

9.5.3 Current Plant and Animal Pests

The long establishment of exotic weed species on the Port Hills means that species found in Cashmere Forest are common to most adjacent properties. Table 9.2 lists some common weeds present in Cashmere Forest.

It is envisaged that pest control operations will be similar to those employed in other CCC Forest Parks like Kennedy's Bush Reserve where similar pests exist. Intensive establishment of systems, bait and trap lines occurs over the first year. This will be followed by regular system reviews through forest monitoring to maximise the effectiveness of operations. Keeping recreational users informed of all pest control operations will be a priority in Cashmere Forest. The use of leg hold traps and bait stations will be especially important for dog owners and parents of young children.

Table 9.2: Biosecurity threats found in Cashmere Forest.

Common Name	Scientific Name	Production	Biodiversity	RPMS
Plant Pests		Threat	Threat	Status
scotch thistle	<i>Onopordum acanthium</i>	Y		
california thistle	<i>Cirsium occidentale</i>	Y		
old mans beard	<i>Clematis vitalba</i>	Y	Y	BP
hemlock	<i>Conium maculatum</i>		Y	
hawthorn	<i>Crataegus monogyna</i>	Y	Y	
broom	<i>Cytisus scoparius</i>	Y	Y	CCP
gorse	<i>Ulex europaeus</i>	Y	Y	CCP
briar	<i>Rosa rubiginosa</i>	Y	Y	
spindleberry	<i>Euonymus europaeus</i>	Y	Y	
radiata pine	<i>Pinus radiata</i>		Y	
flowering currant	<i>Ribes sanguineum</i>	Y	Y	BP
blackberry	<i>Rubus fruticosus</i>	Y	Y	
elderberry	<i>Sambucus nigra</i>	Y	Y	
browntop	<i>Agrostis capillaris</i>	Y	Y	
sweet vernal	<i>Anthoxanthum odoratum</i>	Y	Y	

cocksfoot	<i>Dactylus glomerata</i>	Y	Y	
Feral Animal Pests				
brushtail possum	<i>Trichosurus vulpecula</i>	Y	Y	BP
red deer	<i>Cervus elaphus</i>	Y	Y	
mustelid	<i>Mustelid spp.</i>		Y	BP
hare	<i>Lepus europaeus</i>	Y	Y	
rabbit	<i>Oryctolagus cuniculus</i>	Y	Y	CCP
Domestic Animal Pests				
cattle	<i>Bos taurus</i>		Y	
goat	<i>Capra hircus</i>	Y	Y	
cat	<i>Felis domesticus</i>			
dog	<i>Canis familiaris</i>			
CCP - Containment Control Pest, BP - Biodiversity Pest (RPMS 2005)				

9.5.4 Plant Pest Management

All plant pest control will be consistent with national and regional guidelines which are incorporated in guidelines proposed for Cashmere Forest (NZFOA 2006). This will include the correct certification of all pest control staff. Specific pest containment and control requirements outlined in the RPMS (2005)³² are also to be adhered to.

Production Forest

Weed control methods outlined in section 8.5 Silviculture Regime aim to address the management of biosecurity threats on cutover sites within the production forest. Weed species which survive herbicide treatments on establishment are generally suppressed following canopy closure of the production species.

Non Plantation Areas

The common approach to plant pest management in restoration areas on Banks Peninsula is to concentrate weed control around establishment sites of native seedlings to ensure good initial survival and growth. These methods are outlined above in section (iv) Establishment. Once native species are established it is expected that processes of natural regeneration and succession will facilitate the eventual replacement of weed species with native species (Williams 1983; Wilson

³² <http://www.ecan.govt.nz/NR/rdonlyres/7078AB75-8C26-4EAA-B076-B97F4743CF42/0/CanterburyRegionalPestManagementStrategyweb.pdf> 21/06/2006.

1994; Norton 2005). This process is applicable to restoration in areas under both exotic grassland and/or exotic scrub.

While this process is slow, it utilises the ecology of weeds (pioneers) and indigenous species resulting in an inexpensive yet effective means of weed control in restoration areas. Further weed control will be required to establish and maintain recreation tracks and public thoroughfare. Weed control methods employed for these operations will be a combination of herbicide use and mechanical trimming depending on the type of weeds encountered. Plant pests fall into two broad categories, exotic grasses (sweet vernal, cocksfoot, brown top, incl. other grassland pests like thistle, cleavers, vetch, cats ear and clover) and exotic scrub (gorse, broom blackberry, flowering currant, elderberry etc). Mechanical trimming will provide sufficient control for areas of exotic grassland while herbicide use will be required for the control of established woody weeds.

9.5.5 Animal Pest Management

All animal pest control will be consistent with national and regional guidelines which are incorporated in guidelines proposed for Cashmere Forest outlined in Appendix 4. This will include the correct certification of all pest control staff. Specific pest containment and control requirements outlined in the RPMS (2005)³³ are also to be adhered to.

Domestic Animals

Domestic stock including cattle, goats and possibly sheep currently have access to Cashmere Forest. Cattle are occasionally grazed in forest areas adjacent to Graeme McVicars property and on the airstrip both of which are on the North side of the forest. Cattle degrade stream areas by trampling and browsing indigenous riparian regeneration and degrading stream banks and beds. Grazing rights will cease upon purchase of Cashmere Forest preventing further access for cattle.

Goats are currently farmed on an adjacent property in the northwest corner of the forest and gain access to the forest by pushing through the boundary fence. The fence is traditional wire and

³³ <http://www.ecan.govt.nz/NR/rdonlyres/7078AB75-8C26-4EAA-B076-B97F4743CF42/0/CanterburyRegionalPestManagementStrategyweb.pdf> 21/06/2006.

battens and is insufficient for the restriction of goats. Goats significantly impact regenerating native species, restored native species (especially mahoe, broadleaf and tree fuchsia) and planted production species through browsing. Sheep are grazed along Worsleys Track and may also have access to the forest through the boundary fence which is in disrepair. Sheep will also impact on native germination through browsing.

Revoking of grazing rights and the upgrading of boundary fencing along the northern and western sides to a sufficient standard is necessary for the successful exclusion of these domestic animals. Approaching adjacent land owners to discuss stock management and boundary fence upgrading will be a necessity upon purchase of the property. The expense of upgrading boundary fencing should be shared equally between the two parties involved.

Feral Animals

There is visual evidence of red deer, possums, hares, rabbits and mustelids in Cashmere Forest. Rats, mice, feral cats and hedgehogs are also likely inhabitants. All of these species have the potential to impact on biodiversity and production values in Cashmere Forest and on adjacent properties (Coomes *et al.* 2003; Sweetapple *et al.* 2004; Murphy *et al.* 1998). While it is plausible to permanently remove red deer from Cashmere Forest the majority of pest control will aim to reduce populations and minimise the impacts of resident pest species.

Red deer are currently impacting biodiversity and production values in Cashmere Forest. Antler rub on radiata pine and high levels of browsing are evident in regenerating native species. Red deer are also vectors for bovine tuberculosis (TB). Shooting is seen as a feasible option for the removal of this species due to the small population and limited size of the forest. The possibility of re-introduction following removal is moderate as other small populations exist on the Port Hills. Monitoring of restoration success and production forest inventories should identify re-introductions following removal.

Possums are present in Cashmere Forest and pose a direct threat to biodiversity and production values through browsing of indigenous and production plant species, predation of bird eggs and as vectors of TB. Bait stations and/or trapping techniques will be employed as effective ways of reducing possum populations in Cashmere Forest. Monitoring of production forest re-

establishment, restoration success and forest birds will provide efficacy feedback on possum control techniques.

Hares and rabbits are current threats to biodiversity and production values in Cashmere Forest and surrounding properties. Browsing of newly planted production species and restored and regenerating indigenous species by hares and degrading of surrounding farmland by rabbits are potential impacts arising from these species. Restoration monitoring and establishment inventories of production species will provide information on population size and the required intensity of control.

Mustelid species are currently a biodiversity threat in Cashmere Forest through predation on indigenous birds and larger invertebrates. Large home ranges, wide dispersal, fluctuating population numbers and the furtive natures of mustelid species make control difficult (Norton 2005). Monitoring of forest bird populations will provide feedback on the effectiveness of control methods.

It is likely that feral and possibly domestic cats, rats, mice and hedgehogs may all be present in or have access to Cashmere Forest. The presence/absence and population sizes for these species will be ascertained as trapping and poisoning programmes are implemented.

Chapter 10

Management Areas and Actions

10.1 Introduction

Management areas provide a means of simplifying forest park management by demarcating areas according to spatial arrangement, topography and likely future management. The actual boundaries for management areas (Figure 10.1) are based on artificial features like roads, and stratum and riparian edges which are inherently linked to the landscape and topography of Cashmere Forest. The proposed boundaries take into account future management planning by avoiding bisecting important feature like riparian areas. Management actions are suggested in this section for each area highlighting forestry, ecological, landscape and recreational goals.

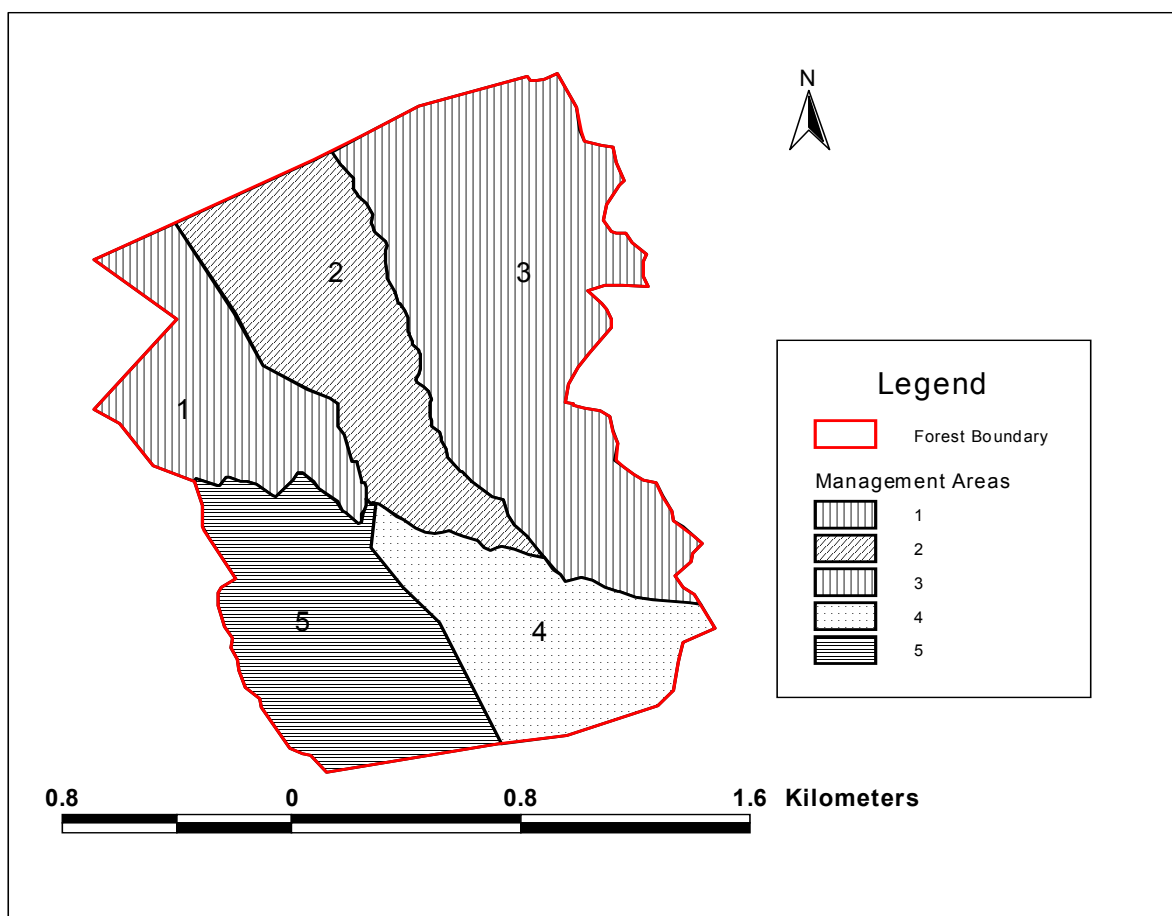


Figure 10.1: Proposed management areas for Cashmere Forest.

10.2 Management Area 1

10.2.1 Description

Note: Limited information is provided on this area as residential subdivision is likely to occur in the short term.

Management area 1 (Figure 10.2) is around 49.7 ha and encompasses Worsleys Valley in the northwest corner of Cashmere Forest. The west side of the valley is bisected by a bluff that runs most of the length of the area, of which only about one third is allocated as non plantation area. The bluff has gentle slopes above running up to Worsleys Road and moderately easy slopes below running down to a main tributary of Cashmere Stream. The area is predominantly under a radiata pine canopy established in 1989. A fire sometime prior to this resulted in several disused salvage tracks on the upper west side and residual fire damaged trees within the area. The current radiata pine is relatively untended with one waste thinning the only silvicultural treatment; as such the trees have only moderate economic potential. The bluff on the west side, a clearing along the southwest and northwest edge, a track area along the southern edge, and stream areas comprise the non plantation areas for this area.

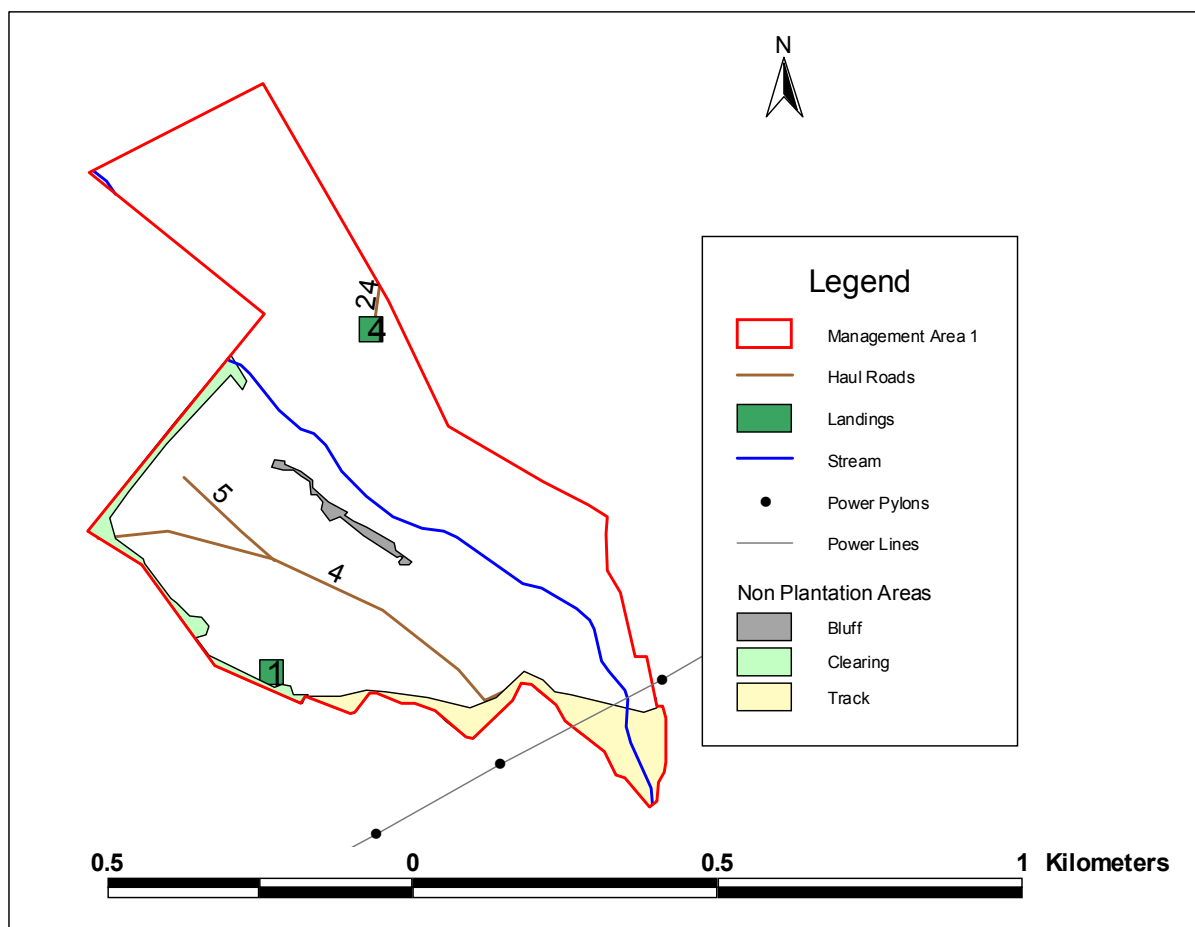


Figure 10.2: Management area 1 and associated features.

10.2.2 Forest Management actions

An approximate schedule of construction and harvesting operations is outlined in Table 10.1. The main access track (MA) is the boundary between management areas 1 and 5, and is therefore only included in Table 10.1. Re-establishment operations for production species will begin taking place around 2017.

Table 10.1: Schedule of earthworks and harvesting operations for management area 1, Cashmere Forest.

Management Area 1		Roads		Landings		Harvesting
Date	Year	Constructed	Utilised	Constructed	Utilised	Stratum
2007	Year 1	MA				
2008	Year 2		MA			
2011	Year 5			1		
2012	Year 6		MA		1	7
2014	Year 8	24		4		
2015	Year 9		MA, 24		4	4
2017	Year 11	7			1	
2018	Year 12		MA, 7			
2025	Year 19	4, 5				
2026	Year 20		4, 5		1, 4	4

10.2.3 Ecological actions

A combination of indigenous restoration and natural regeneration will be employed on the bluff within this area as existing native biodiversity is relatively limited (Figure 10.3). Following harvesting of the surrounding production canopy the re-establishment of production species will begin further back from the bluff, creating space for natural regeneration and restoration plantings.

Indigenous restoration will also be employed in the clearing area along the northwest corner which currently has two components; tussock grassland and mixed shrubland. This clearing is an important restoration priority as it provides an approach to a main park entrance and may be an area of future residential subdivision.

Indigenous restoration will accelerate natural regeneration processes in the planned riparian area in the valley bottom. Riparian areas will be established as coupe harvesting removes the existing radiata pine from the stream area.

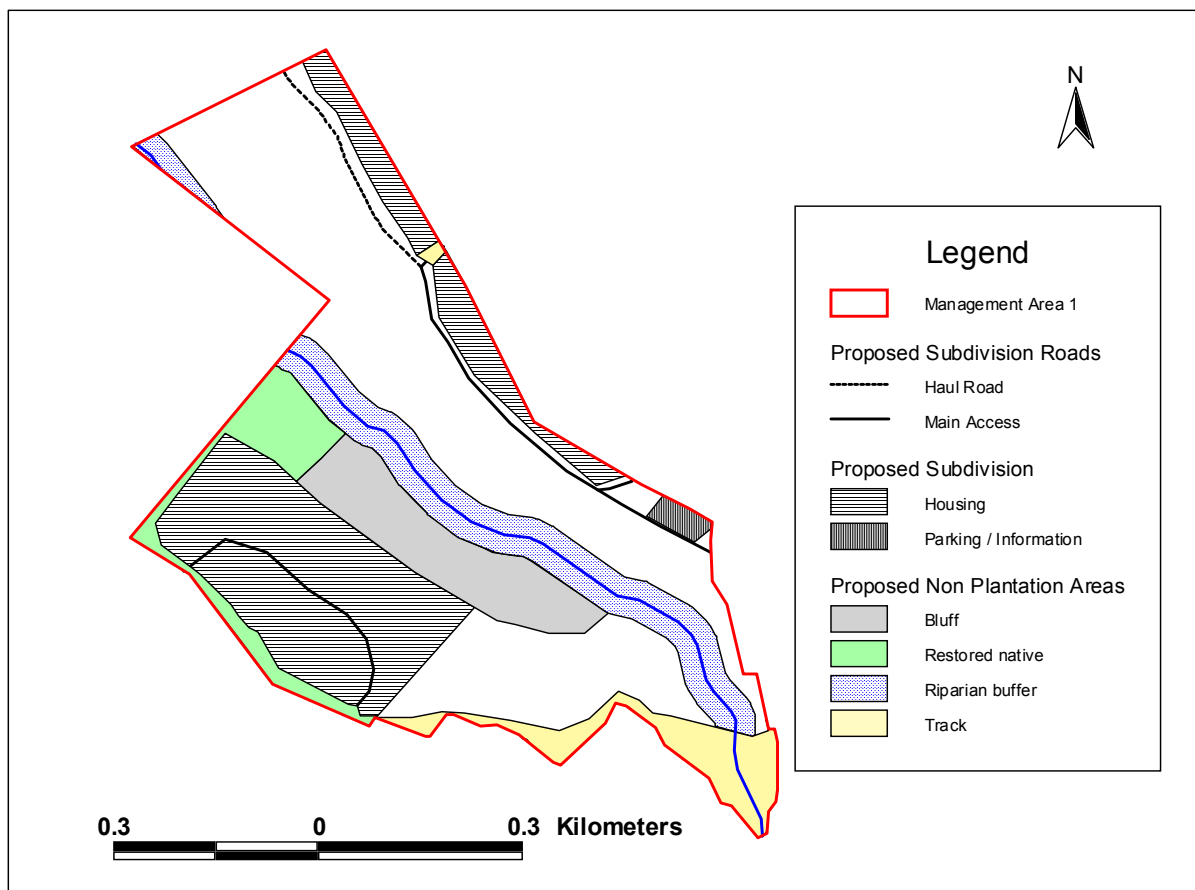


Figure 10.3: Proposed future non plantation areas for management area 1.

10.2.4 Landscape actions

Planting of amenity species, both exotic and indigenous will be important along the western and eastern perimeters of this area where residential subdivision is planned. Amenity plantings on the western side will compliment the indigenous restoration formerly mentioned for the same area, while the eastern side plantings will incorporate public entrance roads and car parks.

10.2.5 Recreation actions

Recreation actions including track construction and facility management for management area 1 are covered in the Cashmere Forest Recreation Plan. The erection of public notice boards at car parks and focal points is recommended for this area.

10.3 Management Area 2

10.3.1 Description

This area, comprising some 70.7 ha is largely made up of the airstrip and lower western slopes of Cashmere Valley the eastern valley in Cashmere Forest (Figure 10.4). The area incorporates the airstrip within its western boundary and runs down to the edge of the planned riparian area along the second tributary of Cashmere Stream which is in Management area 3. The southern boundary is along the main access track. The ridge top airstrip area is relatively easy terrain sloping into moderately steep slopes which run down to the planned riparian area. The production forest is the dominant vegetation type which is made up of 4 strata consisting of a variety of age classes and treatment histories. Non plantation areas include the airstrip (track), a bluff and a small clearing on the northern side of the area. This management area is also bisected by the main power line.

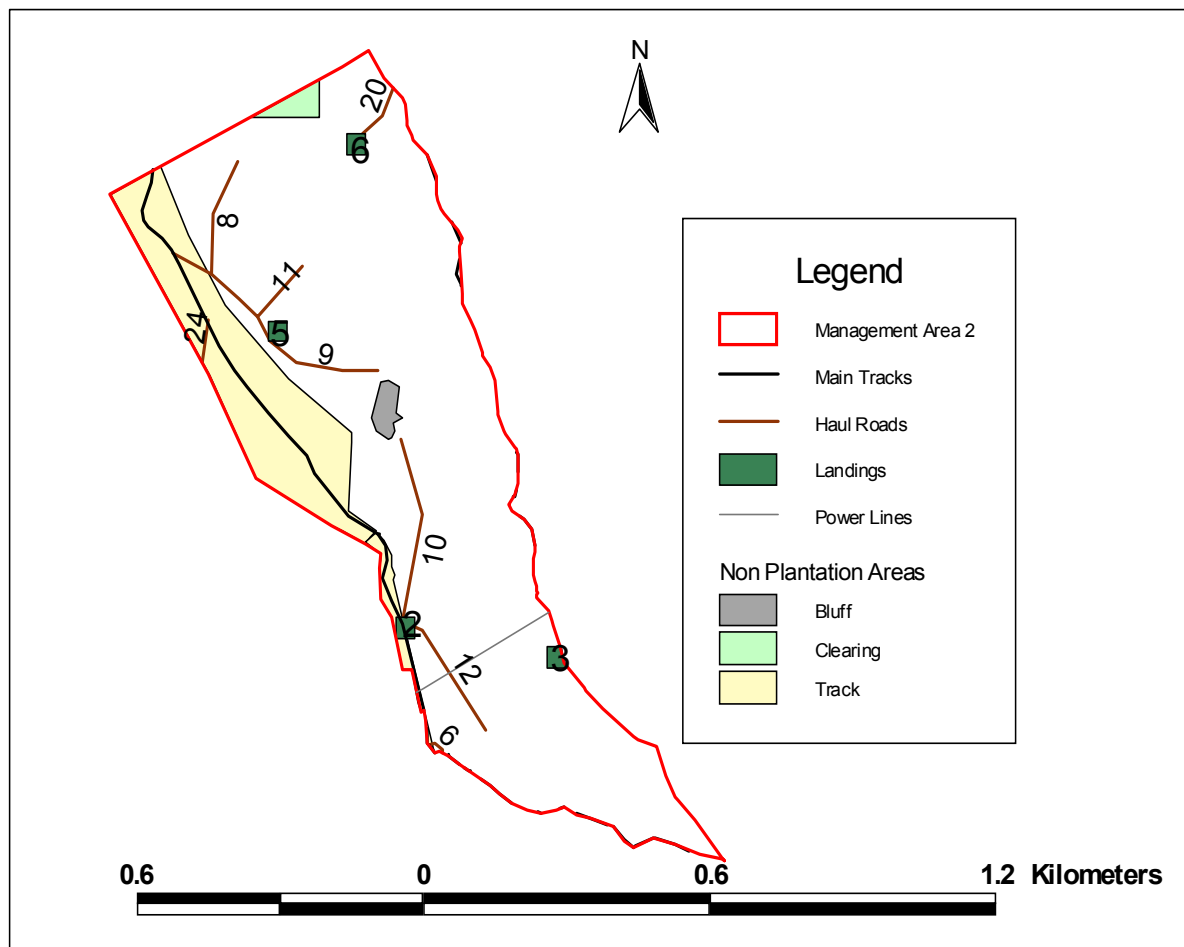


Figure 10.4: Management area 2 and associated features.

10.3.2 Forest Management Actions

Forest management actions begin in year 1 with road and landing construction and harvesting in the following year (Table 10.2). Initial re-establishment operations will commence in 2009. Pruning and thinning activities will be required almost immediately in stratum 2 which has received no silvicultural treatments to date. Harvesting of stratum 6 in 2018 represents the onset of CCM in this area. A portion of the main access track (MA) provides the boundary with management area 4 but is included in this area for construction scheduling.

Table 10.2: Schedule of earthworks and harvesting operations for the first 10 years in management area 2, Cashmere Forest.

Management Area 2		Roads		Landings		Harvesting
Date	Year	Constructed	Utilised	Constructed	Utilised	Stratum
2007	1	MA, 9, 10		2, 5, 6		
2008	2		MA, 9, 10		2, 5, 6	9
2012	6		MA, 9, 10		2, 5	9
2014	8			3		
2015	9		MA		2, 3	1, Dfir
2017	11	8, 11, 22				
2018	12		MA, 8, 9, 10, 11, 22		2, 5, 6	2, 6, 9

The dry north easterly aspect of this area will limit opportunities for the establishment of alternative production species. Relatively moist sites along the upper edge of the planned riparian buffer and where dry watercourses occur offer some possibilities for Mexican cypress or eucalypts.

10.3.3 Ecological actions

Ecological actions in this area will primarily be pest management and biodiversity monitoring in the production forest. Existing indigenous species within the bluff will facilitate natural regeneration of this area with minimal management input. Following the harvest of the surrounding production crop, a new edge for the production forest will be made further back from the bluff allowing expansion of this area through natural regeneration. Indigenous vegetation expanding from the bluff area will eventually connect to plantings along the airstrip (track) (Figure 10.5). Establishment of riparian buffer areas will eventually also occur in this area.

10.3.4 Landscape actions

Landscape actions will include amenity plantings of exotic and indigenous species around planned car parks and residential subdivisions on the airstrip area. Following the harvest of the production canopy along both sides of the airstrip, re-establishment will begin further downslope, expanding subdivision opportunities. The main entrance at the south end of the airstrip will also receive amenity plantings.

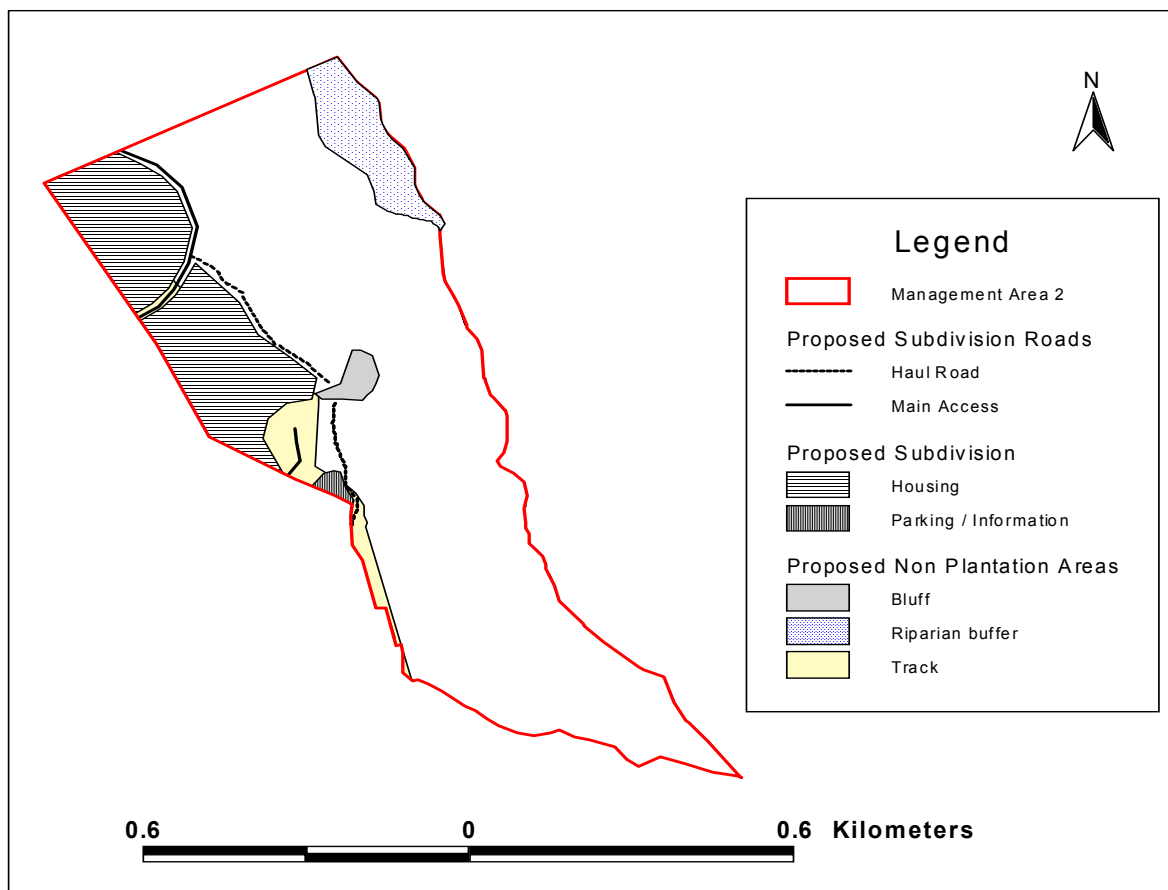


Figure 10.5: Proposed future non plantation, subdivision and road areas for management area 2.

10.3.5 Recreation actions

Recreation actions including track construction and facility management for management area 2 are covered in the Cashmere Forest Recreation Plan. The erection of public notice boards at car parks and focal points is also recommended for this area.

10.4 Management Area 3

10.4.1 Description

Area 3 (Figure 10.6) is the largest management area in Cashmere Forest (134.5 ha) and takes up the majority of the eastern side of Cashmere Valley. The area incorporates the planned riparian buffer along the main valley and extends up to Dyers Pass Road. The predominant aspect is from northwest to south. A large bluff area bisects the valley side extending over the lower third of the area. Above and below the bluff the terrain is sloping but not steep. Further up the valley, terrain is generally all steeply sloping from toe slopes to Dyers Pass Road. The valley side has 6 side streams running from the valley bottom to Dyers Pass Road, 5 of which are in this area. Six production forest strata are represented in this area with a range of treatment histories, most notably around 44 ha of recently established (2002) radiata pine and an area of 25 year old Douglas fir (c. 16.7 ha). This area is bisected by the main power line and a secondary line which is in the northeast corner. The large bluff area, several streams and clearings running under the secondary power line and along the entire eastern boundary make up the non plantation areas in this management area.

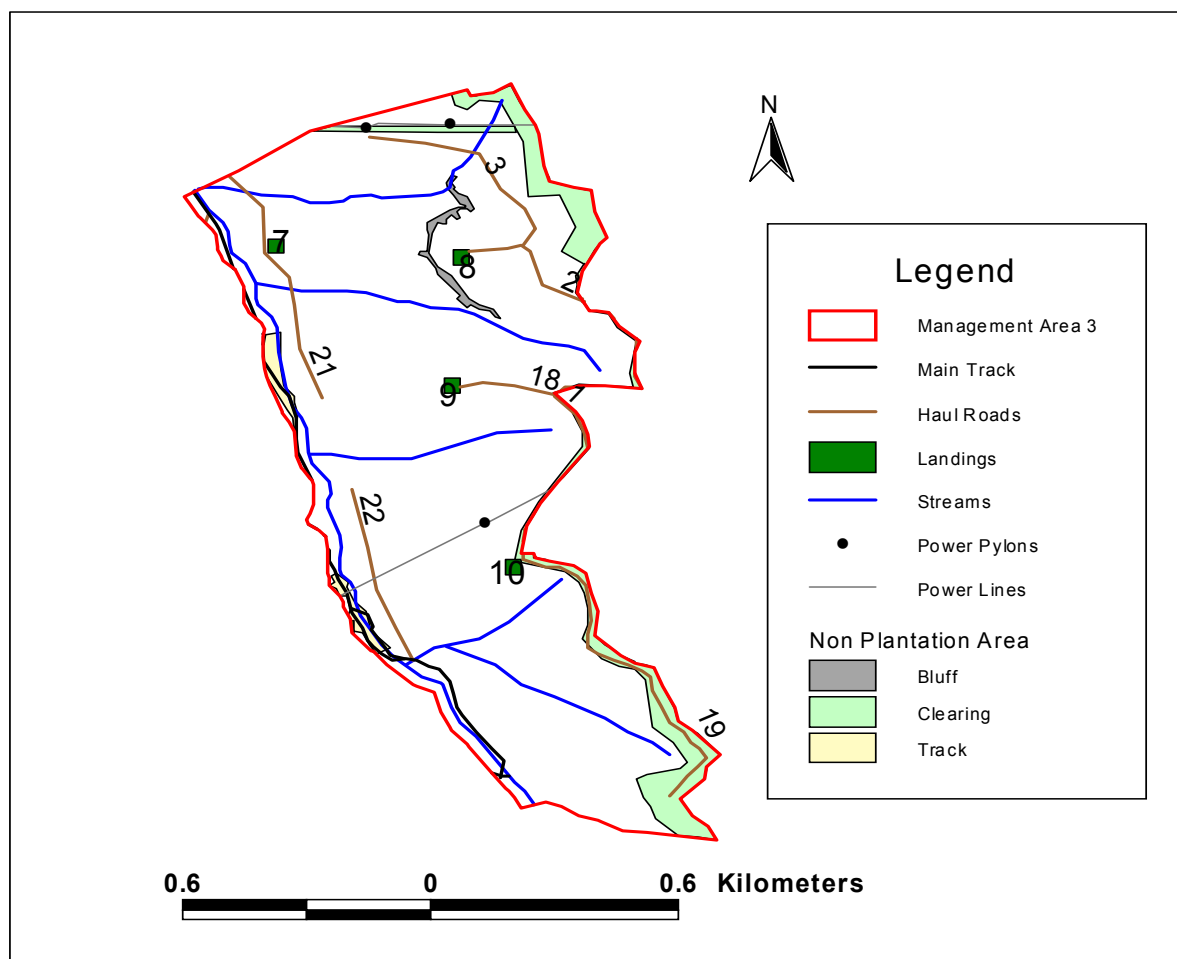


Figure 10.6: Management area 3 and associated features.

10.4.2 Forest Management actions

Upgrading of the main access track which runs through the riparian area of the main valley stream and construction of haul roads under Dyers Pass Road all begin in year 1 (Table 10.3). Harvesting begins in the following year which will include some CCM in stratum 3. Light thinning will be required in stratum Dfir, as mean top height increases in heavily stocked areas.

Table 10.3: Schedule of earthworks and harvesting operations for the first 10 years in management area 3, Cashmere Forest.

Management Area 3		Roads		Landings		Harvesting
Date	Year	Constructed	Utilised	Constructed	Utilised	Stratum
2007	Year 1	MA, 1, 19, 21		7, 10		
2008	Year 2		1, 19, 21		7, 10	3, 5, Dfir
2011	Year 5	1, 2, 3		8		
2012	Year 6		MA, 1, 2, 3, 21		7, 8	3, 5, Dfir
2015	Year 9		MA, 1, 10, 19, 21		7, 10	5, Dfir
2017	Year 11	18		9		
2018	Year 12		1, 2, 3, 18, 21		7, 8, 9	3, 6

Management area 3 offers the most opportunities for alternative production species. Mexican cypress, eucalypt species, coast redwood and Douglas fir will all be established within this area. Those species requiring the most soil moisture will be sited closest to valley bottoms. All alternative species sites will have relatively improved shelter and soil moisture than is normal. Establishment of totara and matai, as production species is also an option as CCM areas expand with high value radiata pine and other alternative species.

10.4.3 Ecological actions

Significant indigenous restoration will occur along the streams in management area 3 as harvesting removes the production canopy from these areas (Figure 10.7). Even though riparian restoration may be quite disjointed initially, it will be a priority for restoration funding due to its ecological significance and the connectivity it provides to Victoria Park for movement of indigenous fauna.

Existing indigenous species within the large bluff area will facilitate natural regeneration processes. Following harvest of the surrounding production crop, a new edge for the re-establishment area will be made further back from the bluff allowing natural regeneration to expand the area occupied by bluff vegetation.

The clearing areas under the secondary power line and along the eastern edge under Dyers Pass Road are currently comprised of pure and associated areas of mixed shrubland and tussock grassland. Although indigenous restoration will be undertaken in all of these areas, the area under

Dyers Pass Road will be a priority as this is a major entry point to Cashmere Forest and will experience heavy recreational thoroughfare.

Indigenous restoration is enjoyed by exotic herbivores and is designed to attract native fauna which in turn attracts predators and other biosecurity threats. Therefore biodiversity monitoring and pest management will be important management actions in this area. Biodiversity monitoring and aquatic surveys will also highlight harvesting impacts and improvements in biodiversity following establishment of alternative production species and riparian areas.

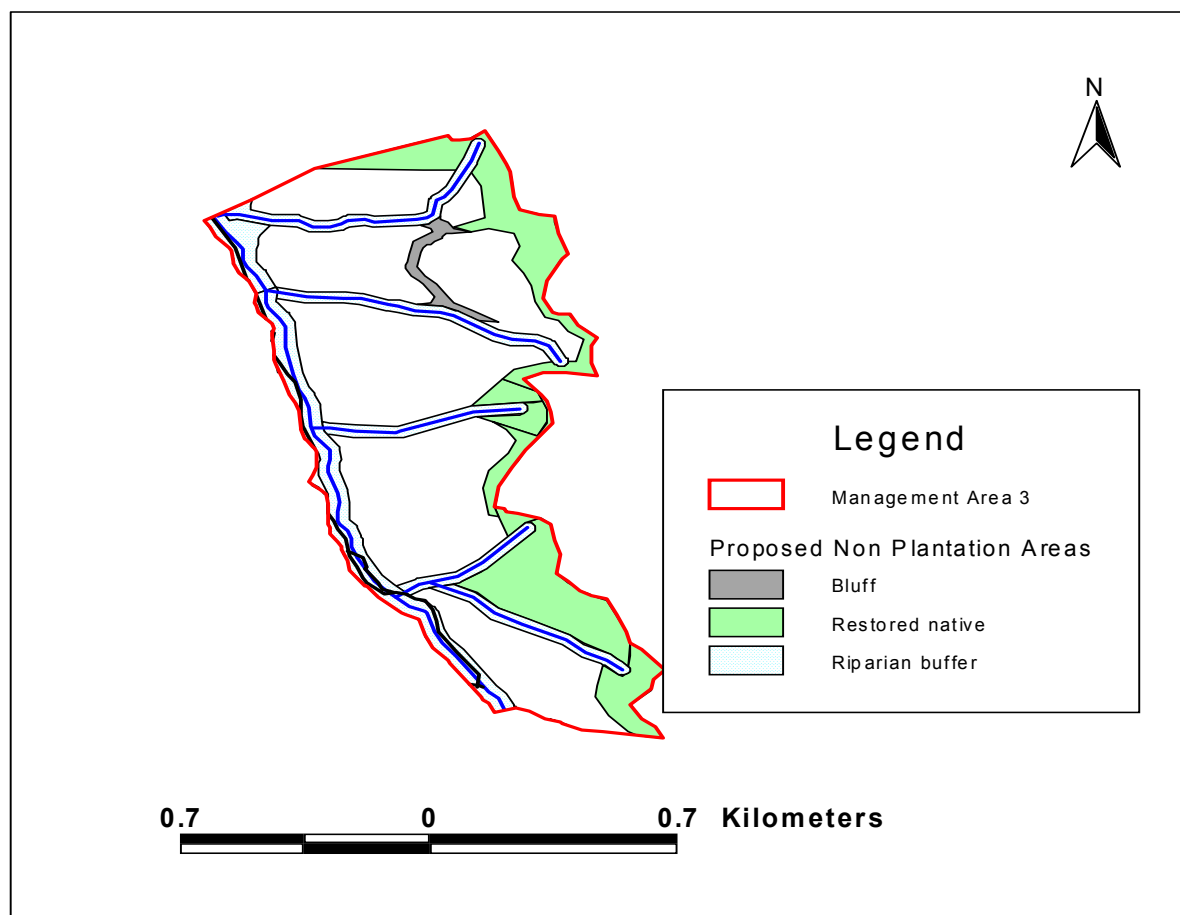


Figure 10.7: Proposed future non plantation areas for management area 3.

10.4.4 Landscape actions

Major entry points near the end of Shalamar Road and on Dyers Pass Road will have amenity plantings of selected exotic and indigenous species to provide connectivity between Victoria Park and Cashmere Forest.

10.4.5 Recreation actions

Recreation actions including track construction and facility management for management area 3 are covered in the Cashmere Forest Recreation Plan. The erection of public notice boards at car parks and focal points is also recommended for this area.

10.5 Management Area 4

10.5.1 Description

Management area 4 (Figure 10.8) is around 55.3 ha and takes up half of the southern face of Cashmere Forest and the upper slopes on the western side of Cashmere Valley. The southern face is generally northwest facing, dry and steep in its entirety from valley bottom to Summit Road. The radiata pine on the southern face is all one stratum which is generally smaller in DBH and shorter than trees of the same age in other parts of the forest.

The upper slopes on the western side are northeast to southeast facing and are also fairly steep with several isolated rock outcrops. The production canopy in this area is also all one stratum but trees are more comparable with the rest of the forest due to more shelter and soil moisture. Occasional dry watercourses occur on the upper western slopes. Non plantation areas include one large bluff and associated clearings that demarcates the western side of the area, and the upper reaches of the main valley stream and one side tributary.

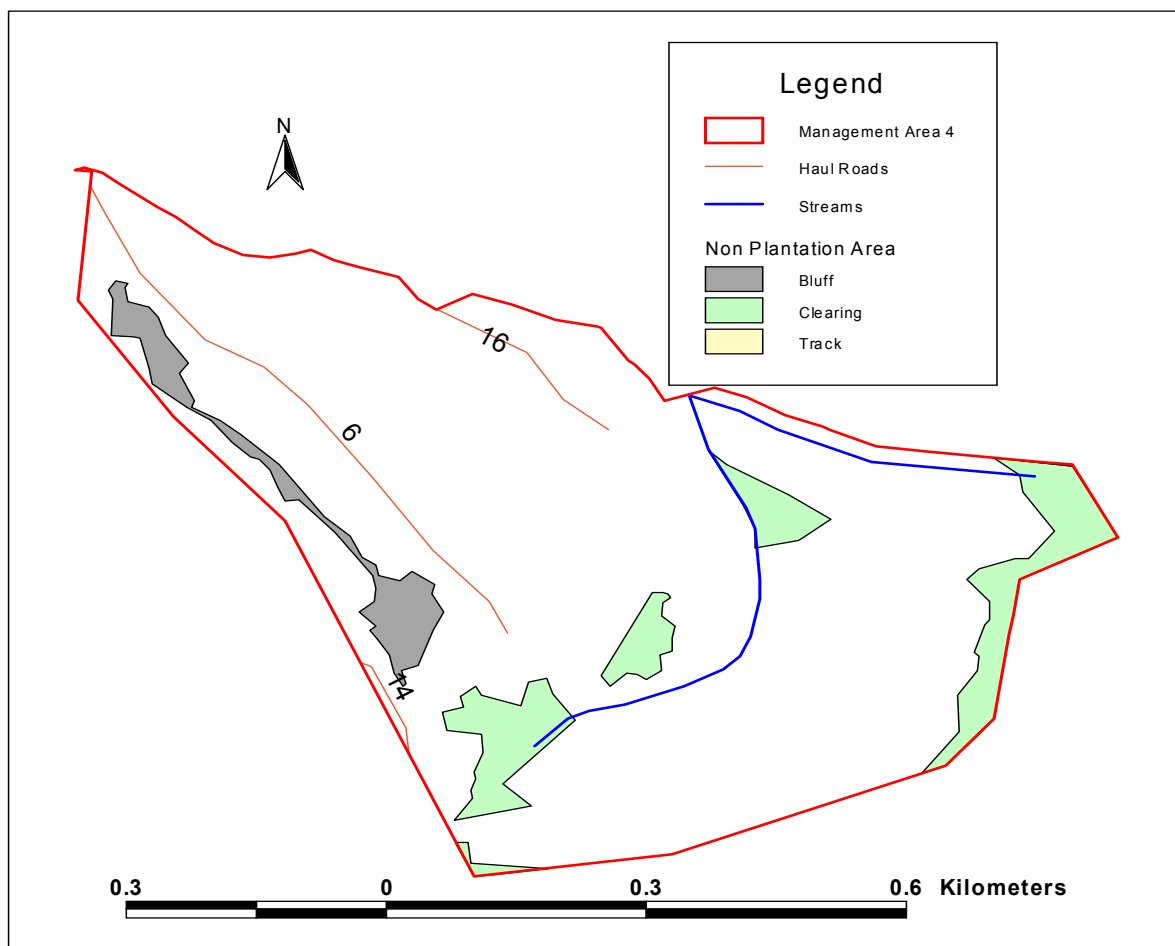


Figure 10.8: Management area 4 and associated features.

10.5.2 Forest Management actions

The construction of road 16 (Table 10.4) provides access for ground based coupe harvesting on easier slopes at the head of the main valley. Harvesting will commence in 2008 with re-establishment of stratum 1 commencing in the following year. Indigenous restoration will be undertaken in Stratum 5.

Table 10.4: Schedule of earthworks and harvesting operations for the first 10 years in management area 4, Cashmere Forest.

Management Area 4		Roads		Harvesting
Date	Year	Constructed	Utilised	Stratum
2007	Year 1	16		
2008	Year 2		16	1, 5
2011	Year 5	6		
2012	Year 6		6, 16	1, 5
2015	Year 9		6, 16	1, 5
2021	Year 15			
2018	Year 12			

Some southerly aspects and sheltered gullies on the western slopes provide opportunities for the selection of alternative production species. Eucalypts, Douglas fir and Mexican cypress will be used in some of these areas for coupe re-establishment. Conversion of ground based coupe areas to CCM following the next rotation will facilitate the establishment of Douglas fir, totara and matai under a high value radiata pine canopy, further diversifying the production component of Cashmere Forest.

10.5.3 Ecological actions

Significant indigenous restoration will be carried out in this management area (Figure 10.9). The entire dry southern face (c.27 ha) is proposed for indigenous restoration following coupe harvesting. The extent of this area precludes quick restoration and presents opportunities for trialling different restoration methods outlined in section 7.3 Indigenous Restoration (Establishment).

Priority for restoration in this area will be the head of the main valley stream and the side tributary. Natural regeneration of the bluff area on the western side will be allowed to expand as the surrounding production edge is pulled back following harvest. Natural regeneration processes will also dominate in the other clearings found in this area as restoration effort focuses on riparian and cutover areas. Species choice will be important on the exposed southern face with species capable of surviving drought and wind exposure favoured.

Plant pest management will be important in this area as harvest coupes may not be artificially restored for several years following cutover. As with management area 3, biodiversity monitoring

and stream surveys will be important for identifying improvements in biodiversity through diversification and/or protection of habitat.

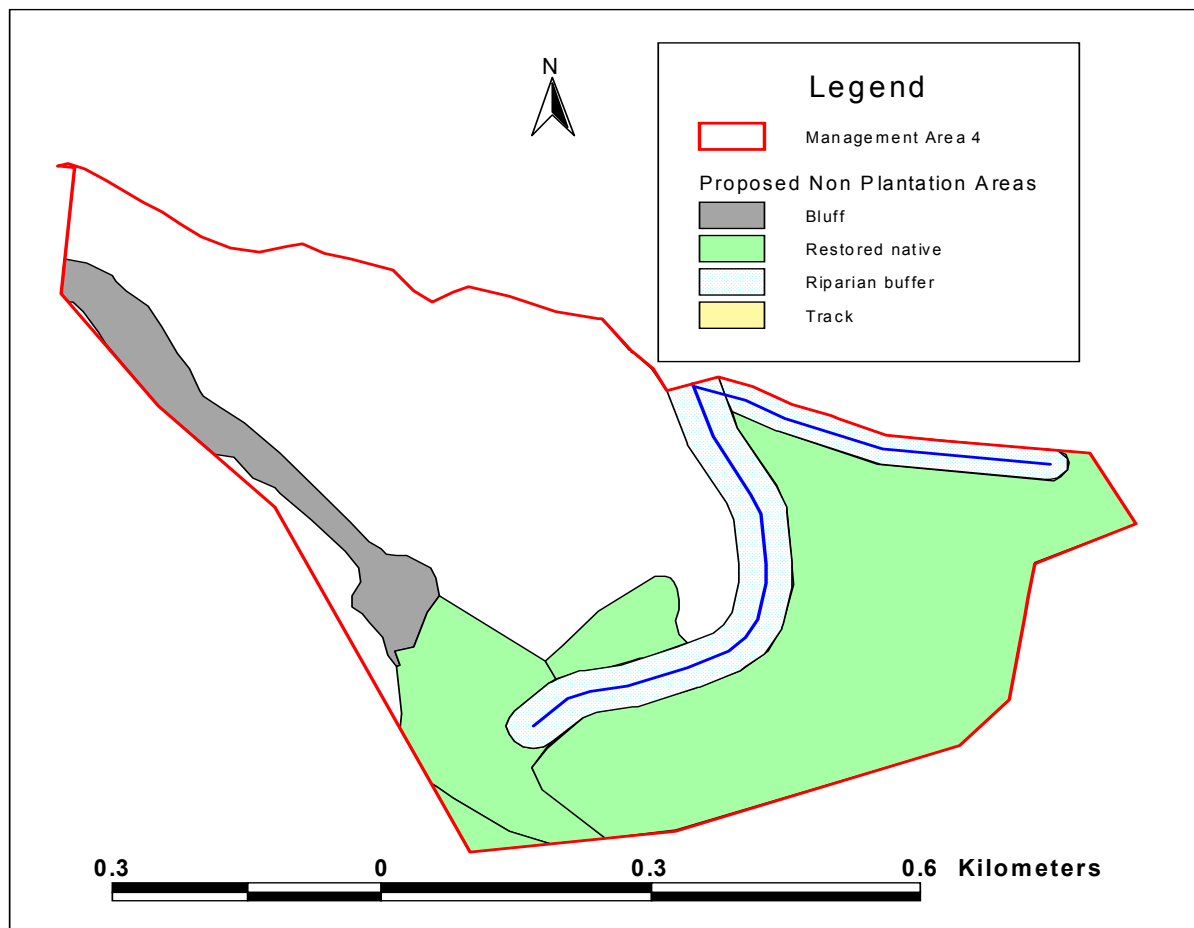


Figure 10.9: Proposed future non plantation areas for management area 4.

10.5.4 Landscape actions

Amenity plantings of exotic and indigenous species will be restricted in this management area to areas along the main access track that bounds areas 2 and 4.

10.5.5 Recreation actions

Recreation actions including track construction and facility management for management area 3 are covered in the Cashmere Forest Recreation Plan.

10.6 Management Area 5

10.6.1 Description

Management area 5 (Figure 10.10) is around 72.8 ha and occupies the southwest corner of Cashmere Forest extending from under Marleys Hill to where the main access track enters off Worsleys Road in the north and management area 4 in the east. The terrain is predominantly easy grading into some steep slopes, bluffs and rock outcrops on the northeast side. This area has the highest elevations and is the most exposed to climatic conditions. There are four production strata represented including a range of age classes (20, 15 and 12 years) and one small area of 12 year old Douglas fir. There are several non plantation areas present in this management area. One bluff and several clearings of tussock grassland with some mixed shrubland.

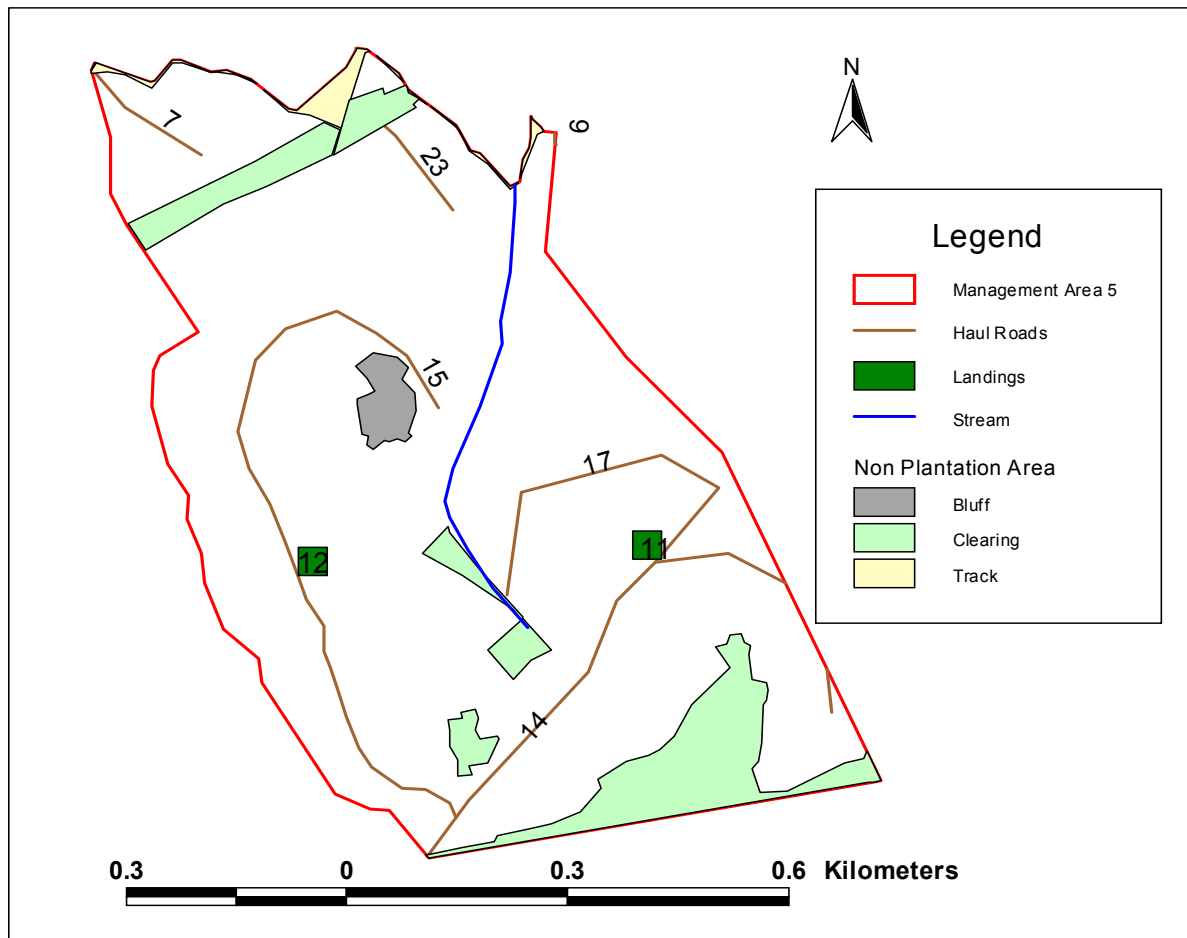


Figure 10.10: Management area 5 and associated features.

10.6.2 Forest Management actions

Forest management actions involving low pruning and thinning of 12 year old radiata pine will be required almost immediately in this area (Table 10.5). While pruning is too late to produce significant amounts of clearwood it will provide access for forest management staff and recreational users. Road construction will not begin until 2011 when roads 14 and 23 and landing 11 are constructed to provide harvest access to this area and management area 4. Harvesting will begin in management area 5 in 2012 with re-establishment commencing in the following year.

Table 10.5: Schedule of earthworks and harvesting operations for the first 10 years in management area 5, Cashmere Forest.

Management Area 5		Roads		Landings		Harvesting
Date	Year	Constructed	Utilised	Constructed	Utilised	Stratum
2007	Year 1					
2008	Year 2					
2011	Year 5	14		11	1	7
2012	Year 6		14		11	5
2015	Year 9		14		11	5
2017	Year 11					
2018	Year 12					

There are potential opportunities for siting of alternative species, eucalypts and Mexican cypress in sheltered gullies as coupe harvesting is undertaken in stratum 7.

10.6.3 Ecological actions

There are currently several non plantation areas in management area 5 and future restoration planning aims to significantly expand these areas (Figure 10.11). The main priority areas for indigenous restoration will be the summit clearing under Marley's Hill and selected recreational lookout points which are common in this area. These areas will be extended in the future to connect to other clearings within the area suitable for restoration. Indigenous species selection for summit and surrounding restoration must reflect likely climatic conditions including high exposure to wind and occasionally snow.

As with other bluff areas, significant existing indigenous vegetation will facilitate good natural regeneration in the bluff area in management area 5. The bluff area will eventually be connected to the western edge of Cashmere Forest through natural regeneration and extensive restoration.

Pest management in this area will focus on ensuring good restoration success. Exotic grasses dominate in existing clearings so restoration plantings will require monitoring and releasing following establishment.

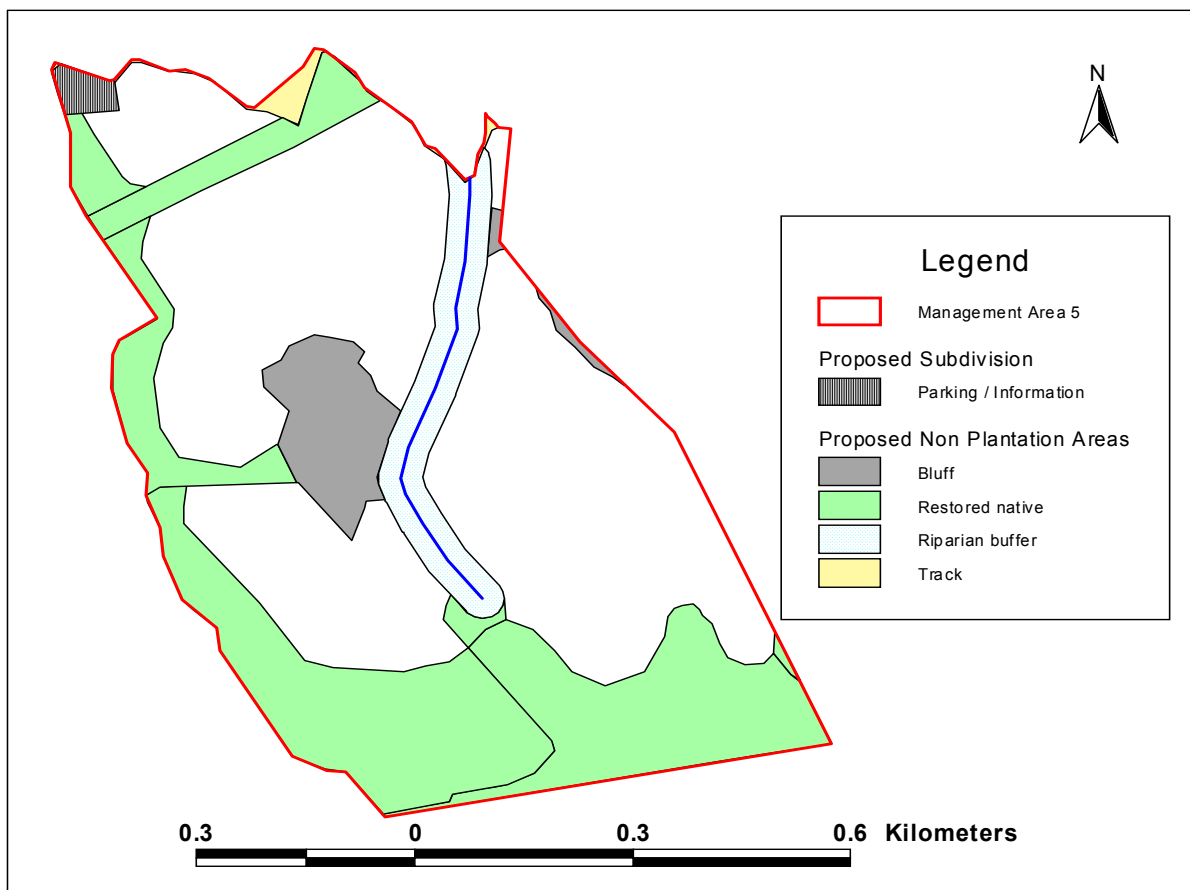


Figure 10.11: Proposed future non plantation areas for management area 5.

10.6.4 Landscape actions

A main entrance at Marley's Hill and several recreational focal points will provide opportunities for amenity planting in this area. Species selection will be important over most of this area where elevation and exposure influence climatic conditions.

10.6.5 Recreation actions

Recreation actions including track construction and facility management for management area 3 are covered in the Cashmere Forest Recreation Plan.

Chapter 11

Monitoring

11.1 Background

This section covers the approach to collection of monitoring information in Cashmere Forest. Information will be collected on growth and yield, establishment success and survival, biodiversity and operations in plantation, non plantation and riparian areas using a range of methods including permanent sample plots (PSP's), random point sampling and transects. This information will provide invaluable feedback for ongoing forest management.

11.2 Plantation Area - Growth and Yield

11.2.1 Introduction

The collection of forest information is essential for accurate planning and forecasting, and maintaining operational integrity in the production component of Cashmere Forest. Forest measurements will be collected through a variety of methods including the use of PSP's, transects and random point sampling. PSP's will be used to collect tree information that allows the assessment of stand growth, health and likely yield. Transects and random point sampling will facilitate auditing and measurement of the success and extent of silviculture treatments and the environmental impacts and integrity of earthworks and harvesting practices.

11.2.2 Forest Measurement

Initial and Mid-Rotation Inventory

Measuring of initial and mid-rotation stand growth is important for providing an indicator of where each stand is in terms of growth, health etc. in relation to the remainder of the forest and against growth models employed for Cashmere Forest. Initial measurements will be carried out in all species at about age 7 following the first prune and thin in radiata pine. Mid-rotation measurement will be carried out at about age 13 in eucalypts and Douglas fir and following the final prune and thin in radiata pine. Subsequent measurements for other alternative species will be carried out around age 20 years. Measurement will be achieved through the establishment of circular bounded PSP's at an intensity of around 1% of stand area. Plot size will be determined by initial stockings. Measurements taken at each of these inventories are:

- DBH of every tree;
- heights of at least half of the trees per plot over a good range of DBH;
- status of trees i.e. pruned height or malformation code.

The employment of students to carry out these inventories will provide educational opportunities while also increasing affordability.

Pre-Harvest Inventory

The pre-harvest inventory provides forest managers with an accurate snapshot of what volumes and log grades to expect following stand harvest. Where coupe harvesting is undertaken sampling should be restricted to the coupe areas scheduled for harvest. Some areas adjacent to the coupe may require sampling to provide sufficient data for good yield forecasting. In CCM areas a sub sample of the entire compartment will require measuring as the nature of this operation harvests trees from the entire compartment. Pre-harvest inventory employs the MARVL system to estimate volume output by log grade and is carried out only in those compartments scheduled for harvest in the following year. As alternative species are established pre-harvest inventory may be restricted to DBH, height and malformation information as MARVL does not recognise some species.

Growth Models

Initial estimates of growth and yield for radiata pine were done using (Cant.) growth models created from a range of plains and foothills data collated c.1960. Growth of the existing radiata pine was also modelled using models created by Zhao (1999) with quite dissimilar results. As pre-harvest inventory information from the existing production crop and future measurements of re-established trees become available an evaluation of which growth models are most suitable to Cashmere Forest is essential. The creation of the forest database of growth and yield information will be essential for future prediction in CCM areas and for alternative species which have limited national growth and yield information.

11.3 Native Biodiversity

11.3.1 Introduction

Ecological monitoring is essential for two purposes. Firstly it provides a measure of success of restoration techniques and natural regeneration. Secondly it provides a means to assess the progression of indigenous restoration and natural regeneration processes towards the long term forest vision. Natural regeneration will be monitored by measuring the extent and abundance of indigenous species in regenerating areas. Indigenous restoration will be monitored by measuring the survival and growth of planted species. Compiling these measurements over time will allow ongoing evaluation of the direction and success of the project as a whole. Structure and content of this section is modelled largely from a similar section in the Tiromoana Bush Restoration Plan (Norton 2005). Annual monitoring plans will be required for scheduling and performing of monitoring operations within Cashmere Forest.

11.3.2 Regeneration Monitoring

Circular bounded PSP's will be established in current non plantation areas selected for natural regeneration. The number of PSP's established will be proportional to area and the type of vegetation present. Each area will be scheduled for PSP establishment according to its ecological

significance as cost and time will preclude mass establishment. The intensity of sampling will be similar to that in the plantation forest of around 1 to 2% for areas of native vegetation and less for predominantly exotic areas. Species presence and abundance will be recorded to assess area expansion and regeneration. It is suggested that a selection of these plots also be used to survey forest fauna including invertebrates.

11.3.3 Restoration Monitoring

PSP's will also be used in restoration monitoring to measure the survival and growth of restored species. The establishment of ecosystem processes like natural regeneration through self and bird dispersed seed will also be monitored. A sampling intensity of 1% of the restored area in any particular year is suggested with circular bounded plots c.100 m². Measuring of plots should be carried out every year for the first 3 and subsequently every 5 years.

11.3.4 Plantation Areas

Biodiversity can be measured simply in the production forest by using PSP's established for forest measurement. Simple species presence and abundance will provide information on the species that survive and grow successfully under a production forest.

11.3.5 Riparian Monitoring

Riparian monitoring will be part of either regeneration or restoration monitoring depending on the treatment designated for particular areas. Monitoring of natural regeneration or restoration will follow the description outlined above.

Further monitoring of stream life and condition is also important. Rectangular PSP's will be established along sections of each stream encompassed by a riparian area to monitor the impacts of harvesting and the effects of riparian establishment on these variables. These plots should be

measured regularly, especially following harvest years. Measurements will reduce over the long term (200 years) but should be maintained. Monitoring will aim to assess both the positive and negative impacts of harvesting and riparian establishment.

11.3.6 Fauna Monitoring

Native fauna, especially avifauna will be an important indicator of success for native regeneration and restoration goals within Cashmere Forest. A recent survey of Cashmere Forest bird populations by Crossland (2003) provides a good point of reference for future monitoring and surveys within the forest. Future bird population surveys should be carried regularly in the future, especially to determine the effect of harvesting operations on population change.

Monitoring population change of invertebrates and other animals like lizards and geckos will also gauge the effectiveness/impacts of native restoration and regeneration and harvesting operations on population characteristics.

11.4 Operations Monitoring

11.4.1 Background

This section outlines the operations that require monitoring within forest management and some ways to carry out this monitoring. All auditing of operations for quality control and compliance purposes will follow a standard monitoring procedure to be set out in the formal harvest plan which should be available to all forest contractors.

11.4.2 Silviculture

Monitoring will be required of all silviculture operations including site preparation, establishment, pruning and thinning.

Auditing of weed control during site preparation is a simple process to undertake by visual assessment of weed survival following herbicide application. Assessments will be based on a percentage of area killed i.e. if all weeds are killed then the operation was 100% successful. Transect sampling of seedling survival following establishment will allow measurement/assessment of establishment techniques and/or seedling health prior to planting.

Auditing of pruning and thinning operations is required immediately following completion of these activities to ensure they have been carried out to the desired prescriptions i.e. the desired quality and intensity for payment purposes. Random point sampling can be used as a quick effective means of assessing this work. A more comprehensive sample of pruned height and stocking will become available following the mid-rotation inventory.

11.4.3 Earthworks and Harvesting

All earthworks and harvesting will be monitored for quality control and compliance with environmental guidelines immediately following completion. Further assessment of roads and landings may be necessary prior to the onset of harvesting operations to ensure sufficient compaction has occurred.

11.5 Yield, Cost and Revenue Information

Records are to be kept for the cost of all operations carried out in the forest, all yield information and all revenues secured from the forest. The collection of this information over the first several years will be vital for updating estimates of these variables used in the initial modelling process. Ongoing collection of this data is necessary for accounting purposes and for development of a more complex set of cost and revenue estimates to reflect changes in terrain, forest type, species etc which will improve forest forecasting and economic planning.

11.6 Land Area Information

Total land area of Cashmere Forest has been estimated through the use of Arcview GIS to analyse aerial photography with ground truthing from handheld GPS units. These methods were also used to update compartment and stratum boundaries to determine an accurate net stocked area (NSA) and non plantation area.

Measuring of coupe harvest areas is to be done initially with a handheld GPS unit but will be updated as recent aerial photographs become available. These coupe areas are important for scheduling and planning of forest operations. Harvest sites under CCM will also be recorded with a hand held GPS unit.

11.7 Storage of Forest Information

11.7.1 Forest Measurement and Biodiversity

Plot location, plot size and number of trees will be recorded for each plot in the GIS under forest compartments and stratum or non plantation area. GIS information will be linked to excel spreadsheets where measured variables from inventories will be stored with calculations of the following plantation stand statistics, stocking, mean DBH, basal area, MTH, mean annual increment (MAI) and pruned height. Pre-harvest inventory information for radiata pine, Douglas fir and eucalypts can be entered into MARVL to determine stand statistics while other alternative species information will be recorded in an Excel spreadsheet. All ecological monitoring information will also be stored in Excel spreadsheets for ease of maintenance and manipulation in the future.

11.7.2 Operations Monitoring and Yield, Cost and Revenue Information

This information will be stored in Excel spreadsheets to provide ongoing records.

11.8 Educational Potential of Cashmere Forest

Cashmere Forest has the potential to provide an excellent educational resource for local tertiary students through jobs involving forest measurement, silviculture, stream and restoration monitoring. These jobs are suitable for both summer and longer term employment and research projects. Liaison should be initiated and maintained between forest managers and local tertiary institutes.

Chapter 12

Project Management

12.1 Introduction

Project management of the Cashmere Forest project will be a complex and delicate task that requires the balancing of a range of interests. Appropriate management is required of forestry, ecological and recreational activities so that they all co-exist and are successful. For this reason it is suggested that one entity is used to manage the entire project. Having one manager will ensure transparency and coordination between activities and reduce potential communication issues. The delicate and complex nature of this project requires diligent and applied management for success. The manager will use the DFM plan as an overarching document while using annual work plans to facilitate actual on-the-ground work. Structure and content of this section is modelled largely from a similar section in the Tiromoana Bush Restoration Plan (Norton 2005).

12.2 Project Management

The project manager will be responsible for overall management of Cashmere Forest. They will implement the harvest, silviculture, restoration, recreation, subdivision and planning review processes. This will be done through scheduling and planning of on-the-ground operations and monitoring in annual work plans and then liaising with appropriate contractors to carry out those tasks. A report must be completed at the end of each year to detail completion and success of those tasks. Also at this time the annual work plans will be prepared for the subsequent year. They will also be responsible for liaising with the Christchurch City Council, educational facilities to organise scientific research or student summer employment and providing general public and stakeholder information.

12.3 Planning Review

An annual review of the Cashmere Forest project is essential to ensure successful management and attainment of the long term vision. A group independent from management and comprising representatives from the PHPTB, Summit Road Authority, CCC and experts in restoration, ecology and forestry sciences, recreation management and others as required will carry out these reviews. The review should cover work undertaken in annual work plans and the overall management plan. Where appropriate, changes may be made/recommended to annual plans and the overall management plan. A separate regular (5yearly) review should be completed of the overall management plan to ensure attainment of the long term vision remains feasible.

12.4 Annual Work Plans

This document is designed as a draft Cashmere Forest Management Plan and as such does not deal directly with Annual Work Programmes. The Cashmere draft Forest Management Plan outlines the general approach for forest management to pursue in order to attain those goals described in Chapter 2 - Forest Vision. Annual work plans will be developed within the constructs of the general forest management approach to ensure all goals of forest management are realised. Annual work plans will deal with the necessary day to day operational activity that will take place in Cashmere Forest in order to realise forest goals and outcomes and will relate to roading, harvesting, silviculture, restoration, recreation and monitoring work that is to be undertaken in the next year.

12.5 Recreation Plan

A draft recreation plan has been prepared as a separate document, but it needs to be fully integrated into the draft Cashmere Forest Management Plan to ensure that there is seamless and integrated management of all values in Cashmere Forest Park.

12.6 Subdivision Plan

The subdivision plan describes the general areas to be subdivided and outlines the requirements for roading, landscaping and surveying to facilitate the subdivision. The subdivision plan is a separate document and is not appended to this draft management plan.

Chapter 13

Closing Statements

13.1 Why is this Cashmere DFM plan important to Cashmere Forest?

The purchase of Cashmere Forest by the PHPTB is a primary requirement for the implementation of this DFM plan. Management actions and options outlined in this plan are generally not applicable to normal forestry operations because of the economic bottom line present in those operations. Sharing of the “bottom line” between successful forest management, and ecological, landscape and recreational values was initially prescribed by the PHPTB and is realised in this DFM plan. If implemented this DFM plan will facilitate a unique opportunity for a diverse forest park environment.

Current and likely future legislation concerning controls on landuse in the Christchurch City area, which encompasses Cashmere Forest, has caused local forestry operators to avoid purchasing the area before this time. Management options like coupe harvesting and CCM which become feasible in a forest park environment facilitate the implementation of forestry operations that are more conducive to strict landuse controls providing further inducement for their implementation.

13.2 What happens to Cashmere Forest now?

The plantation component of Cashmere Forest is currently self sustaining. Operations that require immediate attention are limited and include pruning and thinning activity in stratum 2. In some areas of stratum 2 this activity will only serve to improve internal stand access by reducing stocking. Large DBH's and consequently diameter over stubs (DOS) following pruning, result in minimal clearwood production and reduce the value from pruning operations. However in other areas thinning is required immediately as natural regeneration of radiata pine is competing with planted trees. Mature forest compartments will continue to grow and improve in value the longer they remain unharvested.

Natural regeneration processes are currently at work in non plantation areas of Cashmere Forest. Biodiversity will continue to improve in these areas as native tree and shrub species disperse and colonise the previously exotic grassland communities. As tree and shrub species increase so will native bird species, improving dispersal mechanisms and biodiversity.

Inventory information collected over the summer of 2005/2006 will remain the property of the PHPTB as will the location of PSP's established for the purpose of collecting that information (Appendix 7). This DFM plan and thesis document will hopefully provide the PHPTB with the guiding principles and knowledge to achieve the successful purchase of the Cashmere Forest and implement their vision for the area.

13.3 Final Steps to implement Cashmere DFM plan

The following are some final processes required before implementation of the cashmere DFM plan can be implemented

13.3.1 Incorporate the Recreation plan into Cashmere DFM plan

The recreation plan prepared by Grant McLeod needs to be fully integrated into the Cashmere DFM plan to ensure that there is seamless and integrated management of all values in Cashmere Forest Park.

13.3.2 Confirm Cashmere DFM plan vision and goals with the PHPTB

The 200 year vision and 30 and 5 year outcomes of the Cashmere DFM plan require confirmation from the PHPTB to ensure that they are consistent with the overarching goals for Cashmere

Forest envisaged by the PHPTB. This should be completed at the review meeting planned for the 5th of December 2006.

13.3.3 Seek independent review of Cashmere DFM plan

The masters thesis which incorporates the Cashmere DFM plan will be submitted to an independent external reviewer in March 2007.

13.4 Possible impediments to the Success of the Cashmere DFM plan

13.4.1 Subdivision

There are several ways that the subdivision could impact the Cashmere DFM plan including:

- allocation of too large an area that will impact on operational access for harvesting of adjacent production stands;
- allocation of too small an area that does not generate sufficient income for the purchase of Cashmere Forest;
- dissatisfaction of future subdivision purchasers with forestry operations carried out in Cashmere Forest possibly due to noise, dust, aesthetic appeal.

13.4.2 Cashmere DFM plan vision and goals

Lack of agreement over the 200 year vision and 30 and 5 year outcomes by the PHPTB and/or Christchurch City Council has the potential to impede implementation of the Cashmere DFM plan. This can be minimised through discussion at the PHPTB and stakeholder review meeting planned for the 5th of December 2006.

13.4.3 Major disturbance event

It is important to consider likely responses following a major disturbance event like fire, wind, snow or drought. A major disturbance event could have a significant effect on the economic viability of the plantation component of Cashmere Forest. The risk of fire is addressed somewhat in NPV calculations by allowing for a fire insurance cost in overheads. However, from past events in Cashmere Forest wind probably poses the greatest threat to the plantation forest. Contingency planning for a major wind event should be implemented in some form. Exploring issues surrounding salvage of windthrown trees and large scale extraction is worthwhile to avoid delays following an event. The amount of time that radiata pine can remain on the ground before degrade starts to occur is limited especially in summer. Issues that may occur are:

- obtaining consent from the regional and city council for salvage operations of larger areas than are usually harvested; and
- contracting harvesting crews at short notice.

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Appendix 1

GIS Project for Cashmere Forest

1.1 Introduction

As part of the project brief for Cashmere Forest it was requested by the PHPTB that a catalogue of geographic information system (GIS) layers be created to assist future management of the forest. As part of this catalogue GIS work has been completed on forest layout, forest measurement, access roads, haul roads, non plantation areas, management areas and other Cashmere Forest features. All of the GIS work for has been completed at the School of Forestry, University of Canterbury on a student work station using Arcview 3.2a. A Cashmere project was created in Arcview and within this project layers or shape files are created and presented in a view. Any one view may have several layers upon which it is constructed. Each view has an attribute table providing information like spatial and temporal details and forest measurement. Views can also be used to create layouts or maps of key features. A memory device is attached which has a record of the GIS project saved on it.

2.2 List of Views and their Relevance

Cashmere Forest

This view provides topographical information on the area surrounding Cashmere Forest with rainfall, roads and coastline information.

Features

Provides a view dedicated to forest features like streams, dams, water tanks, utility lines and main tracks.

Forest Compartments

This view provides information on forest compartments and strata and any other information that is pertinent to forest layout.

Forest Measurement

This view provides spatial details of inventory plots intended to serve as permanent sample plots (PSP's), established in the summer of 2005/2006.

Future Areas

This view provides a general look at the proposed future management areas for Cashmere Forest including future plantation and non plantation, subdivision and road areas.

Harvest Plan

This view provides spatial details and general information associated with harvesting. In particular, details are provided of landing and haul road placement, potential ground based and cable areas and yarding distances for haulers.

Legal Boundary

A view created solely for creating a legal boundary for Cashmere Forest from council images.

Management Areas 1 through 5

These 5 views give specific information on each management area within Cashmere Forest.

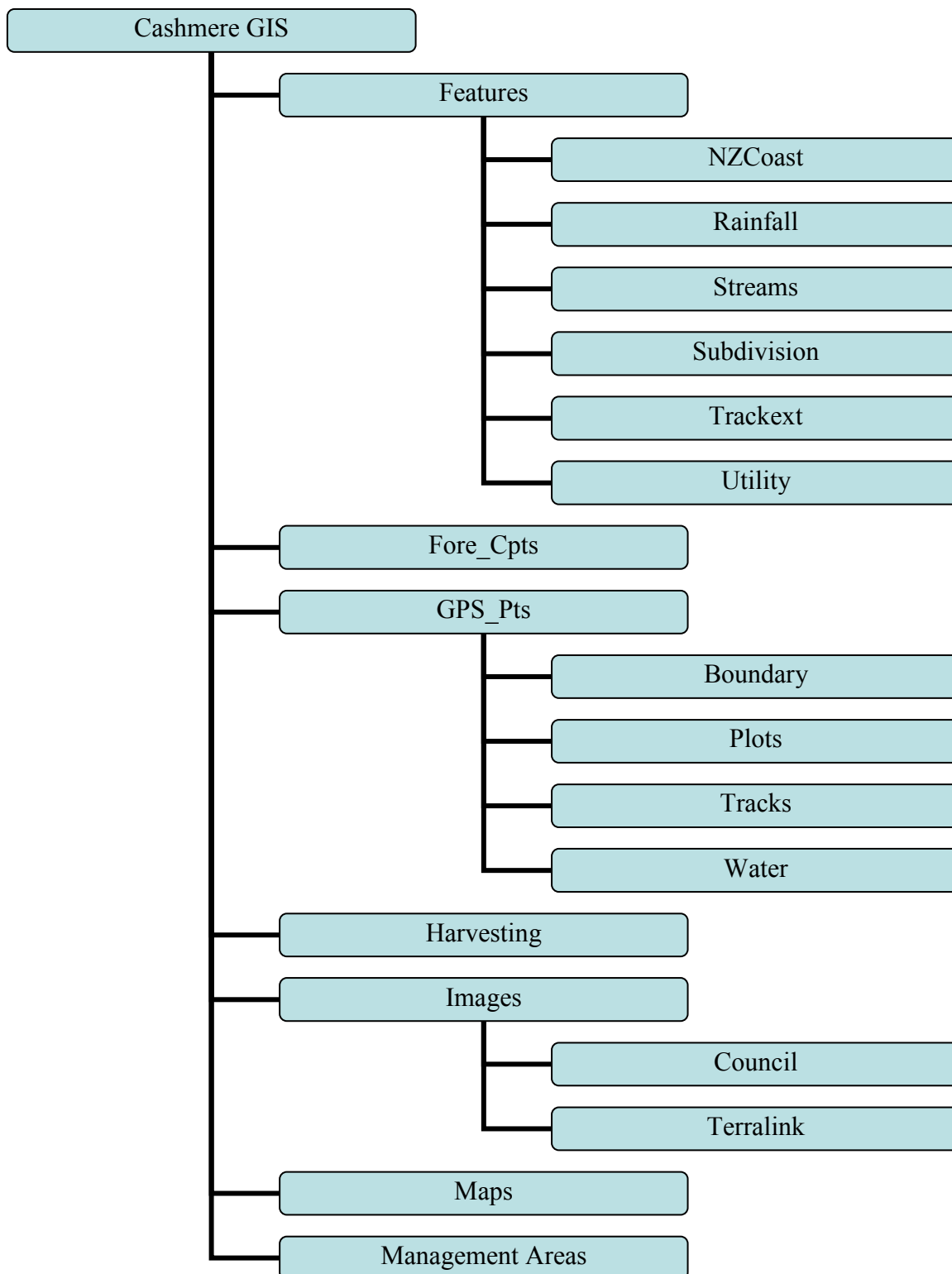
Soil

This view provides information related to soil types in Cashmere Forest.

Subdivision

This view provides specific information around the proposed subdivision of Cashmere Forest.

1.3 Project Folder Layout



Appendix 2

Legal ownership

Cashmere Forest is currently held under 29 titles¹. Numbers 1 through 24 are those tendered for sale (including the right of ways), while numbers 25 to 29 are in addition to those tendered but are currently within the forest boundary.

No.	Owner	Legal Description		Title	Area (ha)
1	McVicar Timber Group Ltd	Lot 2	DP 42834	CB21K/1266	65.98
2	McVicar Timber Group Ltd	Lot 3	DP 42834	CB25A/152	177.59
3	McVicar Timber Group Ltd	Lot1	DP 26504	CB8F/544	4.07
4	McVicar Timber Group Ltd	Lot 2	DP 26504	CB8F/545	4.21
5	McVicar Timber Group Ltd	Lot 3	DP 26504	CB8F/546	4.21
6	McVicar Timber Group Ltd	Lot 5	DP 26504	CB8F/547	4.90
7	McVicar Timber Group Ltd	Lot 6	DP 26504	CB8F/548	4.91
8	McVicar Timber Group Ltd	Lot 7	DP 26504	CB8F/549	4.45
9	McVicar Timber Group Ltd	Lot 1	DP 26722	CB8F/908	5.58
10	McVicar Timber Group Ltd	Lot 2	DP 26722	CB8F/909	6.51
11	McVicar Timber Group Ltd	Lot 3	DP 26722	CB8F/910	6.25
12	McVicar Timber Group Ltd	Lot 4	DP 26722	CB8F/911	6.32
13	McVicar Timber Group Ltd	Lot 5	DP 26722	CB8F/912	5.96
14	McVicar Timber Group Ltd	Lot 6	DP 26722	CB8F/913	5.73
15	McVicar Timber Group Ltd	Lot 7	DP 26722	CB8F/914	5.46
16	McVicar Timber Group Ltd	Lot 8	DP 26722	CB8F/915	5.51
17	McVicar Timber Group Ltd	Lot 9	DP 26722	CB8F/916	4.16
18	McVicar Timber Group Ltd	Lot 10	DP 26722	CB8F/917	4.38
19	McVicar Timber Group Ltd	Lot 11	DP 26722	CB8F/918	4.44
20	McVicar Timber Group Ltd	Lot 12	DP 26722	CB8F/919	5.36
21	McVicar Timber Group Ltd	Lot 13	DP 26722	CB8F/920	5.61
22	McVicar Timber Group Ltd	Lot 14	DP 26722	CB9B/264	5.46
23	McVicar Timber Group Ltd	Lot 15	DP 26722	CB9B/833	5.11
24	McVicar Timber Group Ltd	Lot 16	DP 26722	CB8F/921	5.87
	Right of Way				1.07
	Right of Way				0.47
				Total	359.57
25	McVicar GN	Lot 11	DP 26575	CB8F/903	4.17
26	McVicar GA & McVicar JY	Lot 12	DP 26575	CB8F/904	4.28
27	McVicar GA & Mowat MJ	Lot 13	DP 26575	CB8F/905	4.08
28	Wildbore KMA	Lot 14	DP 26575	CB8F/907	4.21
29	McVicar Timber Group Ltd	Lot 15	DP 26575	CB8F/907	4.54
				Total	21.28
				Grand Total	380.85

¹ <http://www.ecan.govt.nz/ECanMapping/viewer.htm> 04/05/2006

Appendix 3

Indigenous Plant List for Cashmere Forest

Trees, Shrubs & Lianes		Where they occur		
Scientific name	Common name	Bluff	Clearing	Riparian
<i>Carmichaelia australis</i>	NZ broom	x		
<i>Clematis aflojata</i>	leafless clematis	x		x
<i>Coprosma ciliata</i>			x	
<i>Coprosma crassifolia</i>	thick leaved mikimiki	x	x	x
<i>Coprosma melicope</i>			x	
<i>Coprosma propinqua</i>	mikimiki	x	x	
<i>Coprosma rahmnoides</i>	red fruited mikimiki			x
<i>Coprosma robusta</i>	karamu	x	x	x
<i>Cordyline australis</i>	ti kouka, cabbage tree	x	x	
<i>Discaria toumatou</i>	matagouri	x	x	
<i>Fuschia perscandenens</i>			x	x
<i>Fuschia perscandens x colensoi</i>		x		x
<i>Fuschia excorticata</i>	tree fuschia		x	x
<i>Griselinia littoralis</i>	kapuka, broadleaf	x		x
<i>Helicyum spp.</i>		x		
<i>Heliohebe lavaudiana</i>	banks peninsula hebe	x		x
<i>Hypolepis ambigua</i>	rough pig fern			x
<i>Kunzea ericoides</i>	kanuka	x	x	
<i>Melicytus alpinus</i>	porcupine shrub	x		
<i>Melicytus ramiflorus</i>	mahoe, whiteywood	x	x	x
<i>Myrsine australis</i>	red matipo	x		
<i>Leucopogon fraseri</i>	dwarf mingimingi	x		
<i>Muehlenbeckia axillaris</i>	creeping pohuehue	x	x	
<i>Muehlenbeckia complexa</i>	scrub pohuehue	x	x	
<i>Parsonia capularis</i>	jasmine	x		
<i>Parsonia heterophyllis</i>	jasmine	x	x	
<i>Phormium tenax</i>	flax, harakeke	x	x	
<i>Pittosporum crassifolium</i>	karo			x
<i>Pittosporum tenuifolium</i>	kohuhu, black matipo	x		x
<i>Pseudopanax aboreus</i>	whauwhaupaku, five finger	x	x	
<i>Pteridium esculentum</i>	rahurahu, bracken	x	x	x
<i>Solanum laciniatum</i>	poroporo	x	x	
<i>Sophora microphylla</i>	SI Kowhai	x	x	x
<i>Sophora prostrata</i>	dwarf kowhai	x	x	
<i>Utricia ferox</i>	stinging nettle	x	x	

Herbs, ferns and grasses		Where they occur		
Scientific name	Common name	Bluff	Clearing	Riparian
<i>Acaena novae-zealandiae</i>	red bidibid	x	x	
<i>Aciphylla</i> spp.			x	
<i>Asplenium bulbiferum</i> <i>v. gracillimum</i>	manamana, hen & chicken fern	x	x	x
<i>Asplenium flabellifolium</i>	necklace fern	x	x	x
<i>Asplenium</i> spp.				x
<i>Blechnum procerum</i>	small kiokio	x		
<i>Calystegia</i> spp.				x
<i>Carex virgata</i>	swamp sedge	x		x
<i>Chilanthus</i> spp.	dry rock fern	x		x
<i>Clematis foetida</i>		x		x
<i>Cortaderia toetoe</i>	toetoe			
<i>Crassula siberiana</i>		x		x
<i>Dichelachne crinita</i>	long-hair plume grass	x		x
<i>Elymus rectisetus</i>	blue wheat grass	x		x
<i>Haloragis erectus</i>		x		x
<i>Juncus</i> spp.	bull rush			x
<i>Libertia ixioides</i>	NZ iris			
<i>Linum monogynum</i>	NZ linen flax	x		
<i>Luzula banksiana</i> var. <i>orina</i>	coastal woodrush		x	
<i>Oxalis exilis</i>	yellow oxalis	x	x	
<i>Pellaea rotundifolia</i>	round leaved fern	x	x	
<i>Poa cita</i>	wiwi, silver tussock	x	x	
<i>Poa imbecilla</i>	weak poa	x		
<i>Polystichum richardii</i>	pikopiko, common shield fern		x	
<i>Pyrrosia eleagnafolia</i>	round leaved creeper	x		
<i>Rubus schmidelioides</i>	white leaved lawyer		x	
<i>Whalenbergia gracilis</i>	NZ harebell	x	x	

Appendix 4

Regulatory Limitations¹

Permitted Activities Relative to Forestry

Rule 1 Permitted Activities - Area i

The following are permitted activities in Area i, provided that the conditions set out in Schedule 1 are complied with.

1. Earthworks where:
 - the volume is less than 10m³ per site or per hectare²; and
 - the maximum depth of cut or fill is less than 0.5m; and
 - the distance back from a watercourse is greater than 15m.

2. Burning and blanket or strip spraying up to a maximum of 200m² of vegetation except within 10m of a watercourse.

3. Forest harvesting by partial or full suspension systems.

4. Hand clearance and spot spraying of vegetation.

5. Cultivatiuon and mechanical vegetation clearance where:
 - the area is less than 200m³; or
 - the area is greater than 200m³ and the slope is less than 15° and the distance from a watercourse is less than 10m.

¹Taken from - Canterbury Regional Council. 1997. Land and vegetation management regional plan: pt 2. Earthworks and vegetation clearance, Port Hills. pp 35.

² The time period applicable to filling or excavation in terms of volume shall mean the volumes specified may not be exceeded in any continuous period of 10 years.

Rule 2 Permitted Activities - Area ii

The following are permitted activities in Area ii, provided that the conditions set out in Schedule 1 are complied with.

1. Earthworks where:
 - the volume is less than 100m³ per site or per hectare³⁷; and
 - the maximum depth of cut or fill is less than 0.5m; and
 - the distance back from a watercourse is greater than 15m.
2. Blanket or strip spraying vegetation except within 10m of a watercourse.
3. Forest harvesting by partial or full suspension systems.
4. Hand clearance and spot spraying of vegetation.
5. Cultivatiuon and mechanical vegetation clearance on slopes up to 15° except within 10m of a watercourse.

Discretionary Activities Relative to Forestry

Rule 3 Discretionary Activities - Area i

The following are discretionary activities in Area i except where provided for as a permitted activity under Rule 1, provided that the standards and terms in Schedule 2 are complied with.

1. Earthworks where:
 - the volume is greater than 10m³ per site or per hectare³⁸; and / or
 - the maximum depth of cut or fill is greater than 0.5m; and / or

³⁷ The time period applicable to filling or excavation in terms of volume shall mean the volumes specified may not be exceeded in any continuous period of 10 years.

³⁸ The time period applicable to filling or excavation in terms of volume shall mean the volumes specified may not be exceeded in any continuous period of 10 years.

- the distance back from a watercourse is between 7 and 15m.
2. Burning and blanket or strip spraying up to a maximum of 200m² of the vegetation on a property or within 10m of a watercourse.
 3. Forest harvesting where the topsoil is disturbed.
 4. Cultivation and mechanical vegetation clearance in areas greater than 200m² where:
where:
 - the slope is greater than 15°; or
 - the distance from a watercourse is less than 10m.
- Matters to be taken into account in assessing discretionary activities are set out in Schedule 2.

Rule 4 Discretionary Activities – Area ii

The following are discretionary activities in Area i except where provided for as a permitted activity under Rule 1, provided that the standards and terms in Schedule 2 are complied with.

1. Earthworks where:
 - the volume is greater than 100m³ per site or per hectare³⁹; and / or
 - the maximum depth of cut or fill is greater than 0.5m; and / or
 - the distance back from a watercourse is between 7 and 15m.
2. Blanket or strip spraying within 10m of a watercourse.
3. Forest harvesting where the topsoil is disturbed.
4. Cultivation and mechanical vegetation clearance on slopes greater than 15° or within 10m of a watercourse.

³⁹ The time period applicable to filling or excavation in terms of volume shall mean the volumes specified may not be exceeded in any continuous period of 10 years.

- . Matters to be taken into account in assessing discretionary activities are set out in Schedule 2.

Non-Complying Activities

Rule 5 Non-Complying Activities – Area i

1. Earthworks where the distance back from a watercourse is less than 7m, except where provided for as a permitted activity under Rule 1 or as a discretionary activity under Rule 3.

Rule 6 Non-Complying Activities – Area ii

1. Earthworks where the distance back from a watercourse is less than 7m, except where provided for as a permitted activity under Rule 2 or as a discretionary activity under Rule 4.

Schedule 1 (Relative to Forestry)

Conditions for permitted activities

1. The topsoil is not to remain exposed for longer than it takes to resow or replant the area. This time period shall not exceed six months from the time of the disturbance.
2. Culverts and cutoffs are to be installed and maintained to prevent induced soil erosion by leading water safely away from work sites and areas of soil disturbance associated with forest harvesting.
3. No disturbed soil or vegetation shall be discharged into a watercourse where it is likely to give rise to:
 - the diversion or obstruction of a continually flowing river or stream; or

- any significant induced erosion of the bed or banks of any stream; or
- any significant adverse effects on any aquatic ecosystem.

4. Structures, roads, retaining walls, and other works, are to be constructed in accordance with good engineering practice.

Schedule 2 (Relative to Forestry)

Discretionary activities must comply with the following standards and terms.

1. Stormwater controls, watertable cutoffs and culverts are to be installed to ensure that erosion does not occur on the inside edge of the cut.
2. Batters and side castings are to be stabilised by appropriate measures such as seeding, compacting, drainage and / or methods of revegetation;
3. Run-off from water-tables is to be directed to stable land areas;
4. Stream crossings are to be stable or are to be stabilised;
5. A forestry plan, detailing site preparation, roads, tracks, landings and proposed timber extraction methods, is to be prepared for all forest areas over four hectares.
6. Retaining walls and / or other structures are to be designed in accordance with good engineering practice.

Schedule 2 cont.**Matters to be taken into account when assessing discretionary activities.**

When exercising its discretion to grant a resource consent the Council will take the following matters into account.

1. The potential effects on soil erosion, slope stability, adjacent watercourses, and water quality.
2. The effects on the quality of water in rivers, Lake Ellesmere, Lyttleton Harbour, outstanding natural features or landscapes, areas of significant indigenous vegetation and significant habitats of indigenous fauna, mahinga kai areas or sites of importance to Tangata Whenua.
3. The potential for pesticides to enter a watercourse, particularly those used for domestic supply.
4. The potential for adverse effects on neighbouring properties or structures.
5. The potential for adverse effects on the banks or bed of a watercourse, or on its flood-carrying capacity.

Appendix 5

Radiata Pine MARVL Dictionary

Pruned		Sweep < 1/4	A
		Sweep 1/4 - 1/2	B
		Sweep > 1/2	P
	Branches < 7cm	Sweep < 1/4	S
		Sweep 1/4 - 1/2	T
		Sweep > 1/2	P
Unpruned		Sweep < 1/4	J
	Branches 7 - 10cm	Sweep 1/4 - 1/2	K
		Sweep > 1/2	P
		Sweep < 1/4	L
	Branches 10 - 14cm	Sweep 1/4 - 1/2	M
		Sweep > 1/2	P
	Branches > 14cm		P
Unmerchantable			W

< = Fork

> = DBH reduction

+ = Merchantable Branch

* = Broken/dead top

% = Forced cut

^ = Open crown

Appendix 6

Douglas fir MARVL Dictionary

	Sweep < 1/4	S
Live Branches < 7cm	Sweep 1/4 - 1/2	T
	Sweep > 1/2	P
Dead Branches < 7cm	Sweep < 1/4	U
	Sweep 1/4 - 1/2	V
	Sweep > 1/2	P
Live Branches 7 - 10cm	Sweep < 1/4	J
	Sweep 1/4 - 1/2	K
	Sweep > 1/2	P
Dead Branches 7 - 10cm	Sweep < 1/4	L
	Sweep 1/4 - 1/2	M
	Sweep > 1/2	P
Branches > 10cm		P
Unmerchantable		W

< = Fork

> = DBH reduction

+ = Merchantable Branch

* = Broken/dead top

% = Forced Cut

^ = Open crown